THE GREENING CURVE

Lessons Learned in the Design of the New EPA Campus in North Carolina

EPA

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INTRODUCTION

The Greening Curve

Buildings have an enormous impact on the environment. Consuming hundreds of tons of building materials, drawing billions of watts of electricity and burning countless barrels of fuel during each their lifetimes, every home, school, hospital, factory, lab or office that we build will gobble up natural resources and effect pollution for many decades. So when the U.S. Environmental Protection Agency started planning the largest facility in its history, environmental impacts were key considerations. The Agency faced a haunting question–how could EPA build more than one million square feet of labs and offices on a wooded, 132-acre site without making sustainability a key consideration?

The answer was easy. As one of the leading environmental organizations in the world, EPA had to lead by example. But what did this mean in practice? What, exactly, should be done to build a "green" building? On a government project with an average budget, how could EPA pay the price to build a campus that would serve as a model for environmental stewardship? Finding the answers would prove to be quite a challenge, especially since few people believed it was possible to be ecologically smart without being economically foolish.

As EPA began designing this new campus, a revolution was quietly stirring. Designers and builders around the globe were starting to work together to define sustainable building practices. As success stories were shared and new ideas caught on, the green building movement began to emerge.

As the national and international design and construction communities worked diligently to address the issue of sustainability, so did the team that designed the EPA campus. The steep learning curve for green buildings presented countless questions, yet offered few easy answers. Nonetheless, a growing number of architects, engineers, builders and facility owners sought to define for themselves what was needed to build high-performance buildings in environmentally-responsible ways. The project team for the new EPA Campus at Research Triangle Park immersed itself in this dialogue–actively participating and helping to shape many of the discussions.

Thus, the parallel paths met. The new EPA campus took root as sustainable buildings began to grow in number and significance. "The Greening Curve" shares lessons from this common journey in the hope that others will be able to create even better, more environmentally-sound buildings in the future.

EPA Campus Milestones

1984-1991	Planning
1992-1995	Design
1996-1997	Procurement
1997-2001	Construction

Sustainable Building Milestones

1987	"Sustainability" defined by the World Commission on Environment and Development.
1990	American Institute of Architects (AIA) Committee on the Environment established.
1992	Green Building Case Studies start to emerge–Audubon House (New York City), Natural Resources Building (Olympia, Washington) and others.
	Environmental Resources Guide funded by EPA and published by AIA.
	Energy Policy Act passed in the United States
1993	U.S. Green Building Council (USGBC) established.
	Early Green Building Assessment Tools unveiled in Canada (BEPAC) and Great Britain (BREEAM).
	Federal Executive Orders issued on acquisition, recycling, waste prevention and ozone-depleting substances. Other Executive Orders followed through the year 2000, covering energy and water conservation and environmental management.
1995	Federal Guidelines for Buying Recycled issued by EPA (Recovered Materials Advisory Notice).
1996	Sustainable Building Technical Manual published by EPA, U.S. Department of Energy, USGBC and Public Technology, Inc.
1997	Green Developments case studies published by Rocky Mountain Institute.
1998	First U.S. Green Building Assessment Tool released by USGBC as Leadership in Energy and Environmental Design (LEED).
	First International Green Building Assessment Tool created and tested through the Green Building Challenge (GBC) conference in Canada.
	Green Building Advisor guidelines and case studies issued by the Center for Renewable Energy and Sustainable Technology.
	BEES Life Cycle Materials Database first released by the National Institute of Standards and Technology (Building for Environmental and Economic Sustainability–BEES).

Learning Together

The team that created the new EPA campus involved itself in the development of several of these nationally recognized sustainable building tools–such as LEED, the Green Building Challenge, the Environmental Resource Guide, BEES and the Green Building Advisor. Locally, the team also helped craft the Triangle J Regional High Performance Building Guidelines, as well as the "WasteSpec" construction recycling specification which has now become a national reference.

By joining forces with others who were eager to make better buildings, and by tapping EPA's own in-house environmental experts, the design team was able to enhance the quality of the new campus while advancing the broader dialogue on sustainability.

The Team

EPA proved that a state-of-the-art laboratory and office complex can be a model for environmental stewardship without costing extra. The key to this success was a dynamic, creative team approach that involved a radical shift in culture. From day one, the environment was placed on equal footing with cost and performance–a new mindset that helped guide every major decision and ultimately created a model for sustainable facilities.

Key members of the project team are as follows:

U.S. Environmental Protection Agency

As the owner, EPA was a hands-on, active participant in the project. In addition to full-time project managers and engineers, EPA brought researchers and regulatory program experts in as advisors on environmental issues.

U.S. General Services Administration

GSA served as a technical consultant during design and managed the construction phase of the new EPA campus.

U.S. Army Corps of Engineers

The Army Corps of Engineers was the primary design consultant to EPA and GSA throughout design and construction.

National Institute of Environmental Health Sciences

EPA's neighbor and partner on the federal site, NIEHS operates central campus utility services and shares responsibility for the on-site child care center.

Designers–HOK

Hellmuth, Obata + Kassabaum (HOK) Inc. was the lead design firm, and their newly-formed national "Green Team" leader became an integral member of the EPA project team. Major consultants included Roberts/Stacy Group (associated architect), R.G. Vanderweil, Inc. (mechanical/electrical), Greenhorne and O'Mara, Inc. (civil), Weidlinger Associates (structural), GPR Planners (lab design), and Cortell Associates (environmental).

Construction Manager–Gilbane

As a consultant to GSA, Gilbane Building Company provided construction administration and quality assurance services.

Construction Contractor–Clark

Clark Construction Group built the 1.1 million square foot main facility and campus infrastructure.

Design-Build Contractor–Beers

During the construction of the main facility, Beers Construction Company updated and redesigned EPA's National Computer Center and built this separate, 100,000 square foot building on the campus.

The Green Bottom Line

Here's what the team has delivered–a 100-year building, 40% energy savings, 80% construction waste recovery, 100% stormwater treatment through native plants and wetlands on site, soothing daylight in offices, clean indoor air, flexible labs and more–all with no extra budget for building "green."

PROJECT SUMMARY

Project Name
US EPA Campus

Location
Research Triangle Park,
North Carolina

Completion Date
Year 2001

Square Footage
Total gross area: 1,160,000
Net program area: 625,000
- Laboratory space: 270,000
- Office space: 220,000
- Computer center: 70,000
- Building common: 50,000
- Child care center: 15,000

Examples of Materials Used
- 4 acres of concrete block walls
- 35 acres of drywall
- 7 acres of carpet
- 12 acres of ceiling tile
- 2,861 interior doors
- 19.6 miles of telcom conduit

Accomplishments

Site Design
Building fits within contours of site, reducing need to regrade and limiting disruption to habitats and wetlands. Natural woodlands and wildflower plantings minimize water, fertilizer and pesticide use, and reduce associated maintenance costs.

Water Quality
Stormwater runoff is treated naturally using bio-retention, an innovative system that uses soil and plants to remove contaminants from stormwater. Reductions in impervious surface for roadways and parking. increase green space.

The new EPA Campus at Research Triangle Park, North Carolina is home to one of the world's largest groups of scientists, engineers, policy makers and administrators dedicated to understanding and solving environmental problems. With hundreds of environmentally-friendly features, it's also a model "green building" and proof that environmental protection can be accomplished without raising costs.

The new campus is the largest construction project in EPA's history, and from the start, EPA recognized it had a once-in-a-lifetime opportunity to lead by example. EPA chose to build a home that strongly reflected the missions to be carried out within its walls. While providing the Agency with flexible, state-of-the-art laboratories and offices, the new campus also embodies a solid environmental ethic in every aspect of design, construction and operation.

The 1.2 million square foot facility is located on a 133-acre site, part of a 511-acre federal campus dedicated to environmental and public health research. It accommodates more than 2,000 people and contains 600 laboratory modules in five laboratory wings, three office wings and a six-story office tower with a cafeteria and conference center. The buildings are organized along a series of atria that act together as a "main street" to enhance communication among professional staff. Laboratory types include chemistry and biology labs, materials testing labs, electronics labs, automobile testing facilities, and large-scale combustion research labs.

The Process

From the beginning, the core design group focused on defining environmental objectives and tracking progress toward meeting them. Work sessions included participation by green advocates, architects, engineers and building users including researchers and administrative officers. One of the most valuable benefits of the process was the discussion between technical and non-technical people. Innovative

solutions emerged from systematically reviewing multiple options, and making comparisons with a variety of functional and environmental benchmarks. The environmental soundness of decisions was tested in every phase of design.

The Importance of Common Sense

Raising questions every step of the way, design team members maintained a focus on their specialties while collaborating across disciplines to identify creative, practical solutions. By stepping back and viewing the whole through the lens of environmental stewardship, large, seemingly obvious issues were uncovered that might otherwise have been overlooked. For example:

Why install non-native turf grass that requires ongoing maintenance and will use 250,000 gallons of water per month in the summer, when we can use wildflowers, native grasses and native woodland plantings that will be more appropriate to the natural site environment and require little care?

Why would water quality ponds that were intended to serve as a passive "natural" technology require the destruction of acres of forestland? Wasn't there a solution that would be less disruptive to the site?

How can we install over seven acres of carpeting into a facility without understanding how the choice of carpeting affects the longevity of the carpet, how maintenance impacts indoor air quality and what the recyclability is at the end of its useful life?

The Result

The facility limits environmental impact throughout all aspects of its design, construction and operation. Within a fixed budget, the project team was able to meet all functional requirements, reduce long-term operating costs and improve environmental performance. The result is a campus that reflects the values of EPA through its stewardship of natural resources while simultaneously demonstrating the added value that can be realized from a sustainable approach to design and construction.

Energy Conservation
Compared with standard new lab/office construction, the EPA Campus uses 40% less energy for a projected savings of more than one million dollars per year–conserving non-renewable fossil fuels and reducing air emissions.

Lighting
Daylighting, high-efficiency lamps and ballasts, task lighting, and smart controls yield savings in electrical energy use and improve lighting quality.

Building Materials
Building materials selected to be durable and low maintenance, and to minimize life-cycle environmental impact. Specifications ensure compliance with environmental requirements, such as recycled content, sustainably-harvested wood and chemical content limits.

Indoor Air Quality (IAQ)
Improved ventilation criteria, special construction requirements and careful selection of materials and finishes promote superior IAQ. A comprehensive IAQ Facility Operations Manual was produced to guide future operations and maintenance.

Waste Recycling
Design accommodates recycling during occupancy. 80% of all construction waste recycled for a diversion of about 10,000 tons of material from local landfills. Design flexibility conserves resources by minimizing impact of future changes.

LESSONS LEARNED

Green Design Is Better Design

In addition to being environmentally responsible, the green design strategies employed for the EPA Campus project provided equal or better performance in terms of comfort, durability and ease of maintenance. Benefits for occupants include greater access to daylight, more fresh air, protected forest and wetland areas and a design that feels more connected to nature.

Green Design Is Affordable

Energy and water conservation, low-impact site design, materials minimization and other choices have clear economic benefits. Green design features with little financial payback can be afforded by making trade-offs in other areas of a project. Balance tough choices with easy wins.

Make the Commitment

Project leaders must make clear, consistent, and unambiguous statements about their commitment to design and build a green building. An owner can underscore their commitment to green design by including environmental design requirements in the design contract.

Focus on the Process

The state-of-the-art for green design is evolving rapidly, and the best green design solutions are highly responsive to their site and the unique requirements of their building type. Focus on the design process to achieve your goals.

Seek out Green Partners

There is a growing community of architects, engineers and builders that are dedicated to developing green buildings. Begin with committed partners that share your vision and enjoy the challenge of green design.

Recruit Environmental Champions

To maintain a focus on green design goals, owners, designers and builders need to identify green champions to lead within their ranks. Green advocates on the team can perform ongoing design reviews and promote multi-disciplinary collaboration to achieve the best solutions.

Identify Performance Benchmarks

Benchmarks put performance data in perspective. Seek out benchmark information that will allow the team to understand "typical" performance as well as the potential for "improved" green building performance.

Tap Into the Sustainability Network

Awareness and knowledge of green design is growing rapidly, and many are eager to share their knowledge in the interest of protecting the environment. Discover extensive resources on the internet and in print, and place a priority on local resources. Talk to others who have been through a green building process, and visit their facilities.

Reconsider Assumptions

Design criteria drive performance. Great savings can come from challenging criteria that may no longer be valid. Encourage the team to raise questions and re-evaluate assumptions.

Make Time for Research

Even though more and more resources are being created to help design teams understand environmental impacts, innovative design solutions will require research to identify the best solutions. Don't rush the process unnecessarily.

Use Models and Evaluation Tools

Energy and daylighting models can help the team make choices that reduce first costs and save energy throughout the life of the project. Green building evaluation tools can bring a comprehensive sustainability focus to the design process, and can help assess actual results for whole buildings and sites. Make a commitment to use energy and daylight modeling and evaluation tools creatively to improve design performance.

Seize Early Opportunities

Make an effort to integrate green design strategies in the early phases of design. While it is never too late to make a better choice, the cost of shifting to greener design alternatives will increase over time.

Use Green Value Engineering

Often seen as a threat to green design because of its focus on immediate savings, value engineering (VE) can be used as a tool for improving environmental performance. To ensure a balanced focus on cost, function and the environment, assign green advocates as full-time participants in the VE process.

Prepare for Construction

Take time to explain green design goals to the construction team. Because green design strategies are still new to many contractors, sessions to educate both management and the workers can be extremely valuable. Establish the environment as a project goal on equal footing with traditional construction goals of safety, quality, budget and schedule.

Follow Through During Construction

Pay close attention throughout the construction process, with a keen eye toward specification compliance and substitutions.

Keep Talking

Make sure that environmental considerations are part of key conversations. It takes constant reinforcement to maintain the focus.

BACKGROUND

In 1968, the Research Triangle Foundation deeded land to the federal government for a "U.S. Public Health Service Research Park," setting aside 511 acres for federal environmental research facilities. The National Institute of Environmental Health Sciences (NIEHS) was the first to locate there in 1980. The National Center for Air Pollution Control, later to become EPA, had recently moved to North Carolina from Cincinnati, Ohio. Without funds for a permanent facility, they set up temporary quarters in leased space in the Raleigh/Durham/Research Triangle Park (RTP) area. As EPA became established in RTP, it expanded into a collection of leased buildings which were not ideally suited to its research needs. This dispersion of staff led to extensive amounts of time spent traveling between buildings.

Between 1984 and 1991, several studies by EPA and GSA evaluated long-term housing alternatives for EPA in Research Triangle Park. The studies consistently found that EPA could not continue to conduct its research programs in the existing leased facilities, and recommended consolidation into a new government-owned facility on the federal site. The studies also found that consolidation would significantly reduce operating costs–saving the government millions of dollars each year while vastly improving laboratory conditions and employee productivity.

In considering housing alternatives, the government also evaluated the option of renovating existing buildings to upgrade laboratories and consolidate the workforce. Although building renovation is often viewed as environmentally preferable to new construction, this was found to be an impractical alternative. EPA owned none of its own facilities, and even the largest was only half the size needed to consolidate operations. Massive investment would have been required to upgrade structural, mechanical and electrical deficiencies and to meet current code requirements. In late 1991, the decision was made to build a new campus when Congress appropriated funds for design.

SUSTAINABILITY

What is Sustainable Development?

Sustainable development was defined by the United Nations World Commission on Environment and Development in the 1987 Brundtland Report, as "those paths of social economic and political progress that meet the needs of the present without compromising the ability of future generations to meet their own needs."[1] In 1993, a year after the Earth Summit in Rio de Janeiro, the World Congress of Architects similarly defined "sustainability" for the architectural community.

Sustainability means meeting our needs today without compromising the ability of future generations to meet their own needs.

—UIA/AIA World Congress of Architects, June 1993

There is general agreement that environmental degradation is accelerating worldwide, and that projected increases in rates of consumption and population growth cannot be sustained. Solutions will require widespread efforts to increase efficiency, reduce pollution and restore ecosystems. With a goal of building in harmony with the natural environment, sustainable development involves a more sophisticated understanding of natural systems than is required by conventional development. Sustainable design solutions also require designers to expand their awareness of the environmental impact related to industrial processes, transportation and construction. Because the impact of buildings and construction on the environment is significant, there is great potential for improving the environment through better design of buildings. This requires a responsibility to act differently than we have in the past to reduce traditional environmental impact.

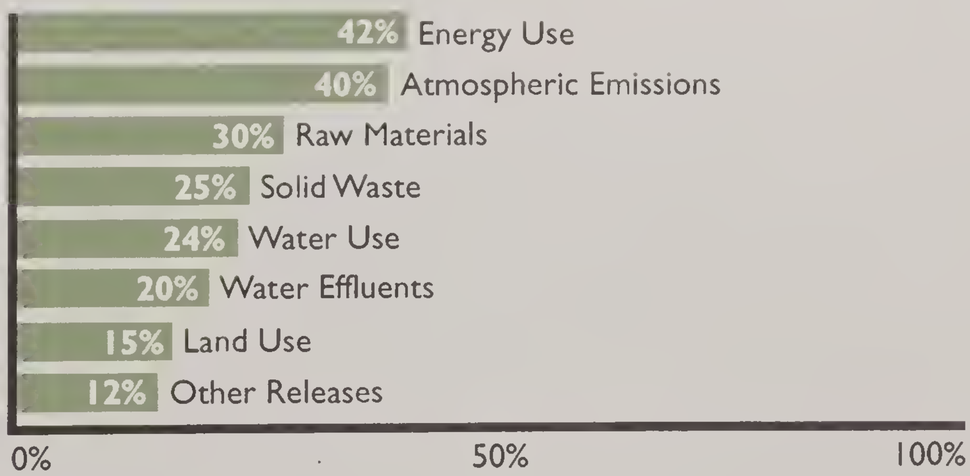
Green Buildings

Roughly one-third of the environmental impact in the U.S. is reported to come from constructing, operating and demolishing buildings. This impact is a result of both the direct and indirect consequences of land use, natural resource depletion, air and water pollution and waste generation.

Green buildings seek to limit adverse impact on the environment and health throughout their entire life cycles–from the acquisition of materials, transportation, construction, use and eventual disuse. To accomplish this,

Environmental Impact of Buildings

Percentage of U.S. nationwide, annual impact



Source: *Worldwatch Institute and U.S. EPA*[2]

A Sampling of Environmental Requirements Mandated by Executive Orders

EO #12843: Procurement Requirements and Policies for Federal Agencies for Ozone-Depleting Substances, 4/93
Requires minimizing procurement of ozone-depleting substances per phaseout schedules outlined in the Clean Air Act.

EO #12873: Federal Acquisition, Recycling, and Waste Prevention, 10/93
Requires EPA to publish federal procurement guidelines for recommended recovered content in certain materials.

EO #12902: Energy Efficiency and Water Conservation at Federal Facilities, 3/94
Requires federal agencies to implement conservation strategies in their buildings as stated in EPACT.

EO #13101: Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition, 9/98
Requires GSA and Department of Defense to develop sustainable design and development principals for the siting, design and construction of new facilities; requires agencies to design new facilities based on lowest life-cycle cost.

EO #13123: Greening the Government Through Efficient Energy Management, 6/99
Requires government to promote sustainable building concepts and help foster markets for emerging sustainable technologies.

EO #13148: Greening the Government Through Leadership in Environmental Management, 4/00
Requires federal agencies to integrate environmental accountability into daily decision making and long-term planning processes across all agency missions, activities and functions.

designers must view the building holistically and consider environmental impact related to site development, transportation and infrastructure, as well as the impact related to the full life-cycle of all building materials and products that comprise the building.

Green buildings represent important steps in the evolution of buildings and communities toward sustainability. As such, they consider all opportunities to:

- Conserve Resources
- Prevent Pollution
- Protect Ecosystems
- Enhance Indoor Environmental Quality

Sustainable Design Resources

When EPA began planning for its new facility, the concept of "sustainable design" was just beginning to gain momentum in the U.S. Only a handful of green case study buildings had been completed, and the information on what to do and how to do it was scarce. In 1990, shortly after the 20th anniversary of Earth Day, the American Institute of Architects (AIA) established the Committee on the Environment (COTE) to begin the process of filling the information void for the architectural profession. In 1991, EPA entered into an agreement with the AIA to work together to create a comprehensive environmental design resource guide entitled the Environmental Resource Guide (ERG). The ERG was first published in 1992 as an AIA publication, and was subsequently republished by John Wiley & Sons in an updated format in 1996, followed by annual updates in 1997 and 1998.

Throughout the 1990s, the "green building" movement continued to evolve. In 1993, the U.S. Green Building Council was formed and began work on a green building rating system for the U.S. In 1996, a comprehensive sustainable design resource guide entitled the Sustainable Building Technical Manual was published by Public Technology Inc. with the support of EPA, the Department of Energy and the U.S. Green Building Council. In 1997, John Wiley & Sons published Green Developments, a compendium of 100 recently completed green building case studies written by the Rocky Mountain Institute. Since this time, additional green design resources have emerged.

Sustainable Design for Federal Facilities

The Energy Policy Act (EPACT) of 1992 was an important milestone in the sustainable design movement because it signaled the federal government's recognition of its own leverage, applied through example and through unparalleled purchasing power. EPACT was signed into law in October 1992, shortly after design work had begun on the new EPA Campus. It provided guidance to federal facility planners on how to improve the energy performance of their agencies, and it set a goal of a 30% reduction in commercial building energy usage by 2005, based on a 1985 baseline. EPACT required that all government buildings "install in Federal Buildings owned by the United States all energy and water conservation measures with payback periods of less than 10 years," and that these conservation measures be evaluated using a life-cycle costing methodology.

EPACT also mandated that each federal agency that constructs at least five buildings a year "designate at least one building, at the earliest stage of development, to be a showcase highlighting advanced technologies and practices for energy efficiency, or use of solar and other renewable energy." Even though EPACT and the subsequent Executive Orders (EOs) were enacted after design had already begun on the new

Campus, it provided additional support and validation to project team members committed to developing the EPA Campus as a showcase facility. In June 1999, the federal commitment to green buildings remained strong as EO #13123 was issued, further advancing the government's pledge to green its facilities.

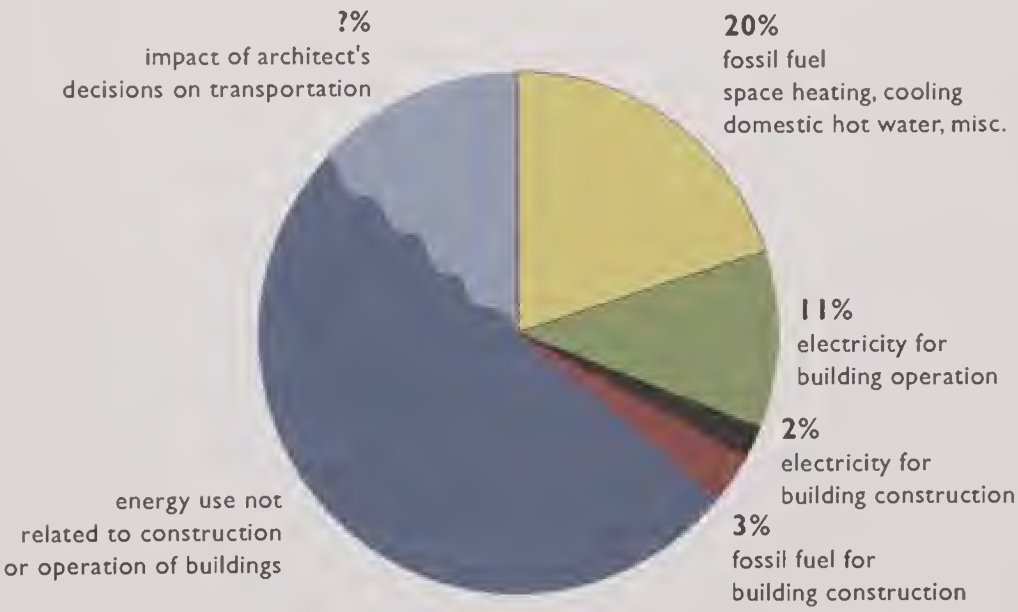
Resource Conservation

Resource use, which includes energy, water and materials, is fundamental to the impact buildings have on the environment. Non-renewable resources are being depleted and many renewable resources, such as timber and water, are being extracted at rates that exceed their ability to be replenished. According to the Worldwatch Institute, three billion tons of raw materials, approximately 40% of all materials entering the global economy, are turned into foundations, walls, pipes and panels for building construction each year.[3]

Green buildings seek to use environmentally-preferable building materials. This refers to all of the products and materials that have reduced the environmental impact over the full life-cycle of the material, as compared to other available options. Conservation of material resources also depends on efficient use of materials, enhanced durability and strategies to encourage re-use and recycling of resources. Green buildings accommodate re-use and recycling so that waste generated by building occupants can be handled properly. Construction waste, which constitutes approximately 25% of municipal landfill content, can also be reduced, re-used and recycled.

Energy conscious design reduces the use of energy resources through improvements to siting, building envelope design and daylighting with energy-efficient electric lighting. Required mechanical systems should be optimized to maximize efficiency, and heat reclaim systems that "recycle" energy for heating, cooling and/or humidifying the air should be investigated.

U.S. ENERGY USE WITH
AREAS AFFECTED BY ARCHITECTURE



Source: NCARB, 1993

Opportunities to Conserve Resources

Energy Use
- Heating and cooling
- Air circulation
- Lighting
- Water heating
- Special equipment
- Plug loads

Water Use
- Landscape irrigation
- Plumbing fixtures
- Mechanical equipment
- Appliances

Building & Site Materials
- Raw material acquisition
- Production processes
- Packaging and shipping
- Installation and finishing
- Durability
- Maintenance
- Waste disposal and recycling

NCARB
The National Council of Architectural Registration Boards is a non-profit federation of 55 state and territory architectural registration boards in the United States.

Sources of Pollution

Energy Use
- Petroleum extraction and refinement
- Oil spills
- Air emissions and nuclear waste from energy usage
- Air pollution from automobiles and other transportation
- Thermal waste
- Ozone-depleting substances

Water Use
- Contaminated runoff
- Waste water
- Water treatment by-products

Materials Use
- By-products from material manufacture
- Wasteful packaging
- Solid and liquid waste
- Hazardous waste

Environmental Impact on Ecosystems
- Displacement of habitat for buildings, roadways and parking
- Increase in impervious surface
- Reduction in groundwater recharge
- Soil erosion
- Contamination of water bodies
- Contamination of groundwater
- Use of invasive exotic plants
- Use of fertilizers and pesticides
- Urban heat island effect

Finally, conservation of water resources in green buildings involves strategies to use less water for HVAC equipment and appliances, flushing fixtures, potable water uses and irrigation. Water harvesting and water re-use strategies can reduce demand for potable water supplies.

Pollution Prevention

Buildings and their sites contribute to the creation of waste and pollution as a result of their use of energy, water and materials. In nature there is no waste because all by-products of natural processes serve as "food" for other processes. Many of the industrial processes employed in the creation of buildings, however, release solid, liquid or gaseous by-products into the environment that serve no useful purpose and are potentially harmful.

Green building design searches for solutions that prevent the creation of pollution at the source. By limiting energy and water use, and making efficient use of environmentally-preferable materials, pollution can be reduced. Integrating environmentally-sound recycling into design solutions can further reduce pollution. Waste treatment followed by safe disposal is required for pollution that cannot be prevented or recycled. On-site, natural treatment options should be considered to treat waste including bioretention, constructed wetlands and composting.

Ecosystems Protection

The impact of buildings on natural ecosystems occurs on multiple levels, including loss of open space and habitat, intrusion on fragile ecosystems, alteration of stormwater flows, erosion and loss of soil resources, contamination of water resources and use of non-native and invasive species or monocultures of vegetation. Green buildings seek to develop "low impact" solutions which work in harmony with natural systems, and minimize disruption to plant and animal habitats. Redevelopment of previously built sites and compact development can limit disruption. Native, low maintenance landscapes, reductions in impervious materials and natural filtration of stormwater can reduce the need for treatment strategies.

Indoor Environmental Quality

In the United States, it has been estimated that people spend more than 90% of their time indoors.[4] This makes the quality of the indoor environment critical. Indoor environmental quality refers to comfort and building-related health and productivity issues that result from the quality of interior lighting, acoustics, thermal control and indoor air quality (IAQ).

Indoor air quality depends upon a variety of factors, including the levels of particulates, volatile organic compounds (VOCs) and molds, bacteria or other biological contaminants in the air stream. Indoor air contaminants can come from building and finish materials, cleaning and maintenance products, mechanical equipment, microbial growth in wet areas, tobacco smoke, radon gas, office machines, exterior pollution and a variety of other sources.

EPA rates indoor air pollution among the top five environmental risks to public health. It has been estimated that unhealthy indoor air is found in up to 30% of new and renovated buildings. Both the long- and short-term health effects of poor indoor air are revealing themselves at an increasing rate due to occupant complaints, while specific IAQ problems are being discovered through testing and monitoring.

Temperature of the indoor environment is also an important factor. American Society of Heating and Refrigeration and Air Conditioning Engineers stipulates that the indoor comfort zone is between 68 degrees Fahrenheit and 82 degrees Fahrenheit, and 20 to 50 percent relative humidity. If people are too hot or too cold, the discomfort will cause inefficiency in their performance.
Equally as important is lighting. Natural lighting generally improves the environment, uplifting people and enhancing their productivity. Electrical lighting should be designed to simulate the effect of natural light.

Acoustics are also a critical factor in the indoor environment. In today's fast-paced office environment, people need quiet spaces that minimize disruptive noise and afford a sense of privacy.

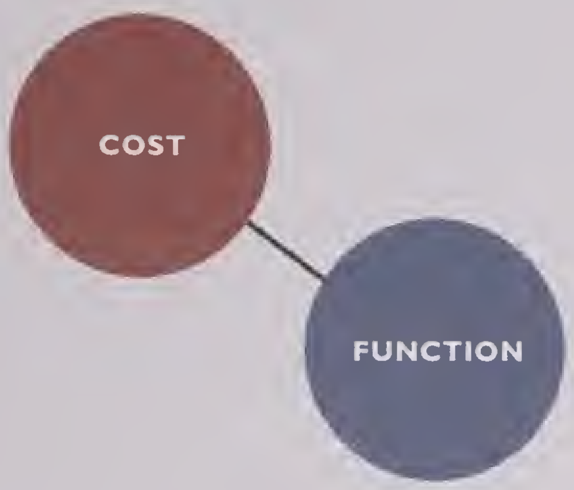
Green building design solutions promote healthy environments while also seeking improved comfort and occupant satisfaction. Recent studies have shown that buildings with good indoor environmental quality can provide significant financial benefits. Effective ventilation, natural lighting, indoor air quality and good acoustics have been shown to significantly increase worker productivity.

Impact on Indoor Environmental Quality

Site & Landscape
- Daylight access
- Reflectivity of exterior materials
- Views, connection to nature
- Noise
- Outdoor air quality
- Vehicle exhaust
- Radon
- Pollen and other allergens

Building & Site Materials
- Chemical emissions from materials, adhesives and finishes
- Microbial contamination
- Respirable fibrous materials

Building Operations
- Ventilation rates
- Temperature control
- Humidity control
- Daylighting
- Electric lighting levels
- Glare
- Acoustics
- Chemical emissions from cleaning materials
- Environmental tobacco smoke
- Noise
- Pest control



Traditional Decision Model

Green Decision Model

DESIGN PROCESS DISCUSSION

Green buildings challenge the norms of the design and construction industry. Design teams must actively search for better alternatives to conventional models to successfully reduce the environmental impact related to buildings and construction. This search requires an improved decision model that balances cost, function and the environment. The result is an approach that expands the traditional "cost-benefit" decision model to one that includes environmental performance as a core value.

Early on, the design team focused on explicitly defining environmental objectives, then tracking progress at each stage of design. To support this effort, an open, collaborative process was established which enhanced dialogue and decision making. The group found that design innovations led not only to the creation of a more environmentally sound facility, but to improved quality and lower operating costs as well.

Even though this green design process required extensive research and investigation of design alternatives, the group found that the overall design process gained efficiencies from the use of an inclusive approach. Guided by clear goals and defined milestones, this approach gave a sharp focus to the design effort, enabling more to be accomplished within the boundaries of a conventional project schedule and budget.

The Right Start

At the beginning of every project, there is an opportunity to define goals and objectives and establish a strategy for meeting them. First and foremost, EPA made a commitment to design and build a green building. From there, the design team proceeded to incorporate environmental design goals into each stage of the planning process.

Making the Commitment

The sheer size of the EPA Campus project–over one million gross square feet of offices and laboratories–magnified the environmental impact of each design decision. Understanding that by its very nature, the construction of the new facility posed a negative impact on the environment, EPA felt a strong responsibility to explore design options that promised to minimize this environmental burden.

In one of the early design reviews, a proposal was presented to route the road leading to the new Campus through an area that featured a 100-year-old Oak tree. The EPA team made a decision to re-route the road rather than sacrifice the tree even though it did require additional time and money. This decision not only sent a message to the entire project team underscoring the commitment to the environment, it represented the reality of moving toward a green facility.

When placed in the context of EPA's organizational mission, this sense of obligation was further magnified. EPA felt that the design and construction of its new facility presented not just an opportunity, but also an obligation to lead by example. As the building owner, EPA would control nearly all design decisions. If done correctly, the Agency believed that its facility could become a functional model for the greening of other public and private sector facilities, and help advance sustainable design and construction as an industry-wide practice.

Defining the Challenge

Before the formal design of the new facility began, EPA set the course for the project by describing the environmental challenge both for itself and for the professional design team it would solicit. Green design criteria were written into the key project documents, including the solicitation for Architect/Engineer (A/E) services, the Program of Requirements (POR), and the contract with the chosen A/E. By clearly and consistently presenting its environmental goals and explicitly integrating them into the project requirements, EPA set a direction for the design firms and established a set of procedures for tracking environmental performance during the design process.

The solicitation for A/E services was EPA's first opportunity to present its vision for the new facility to potential A/E contractors. Recognizing the importance of choosing a partner that would share EPA's vision, the contract solicitation required a "demonstrated corporate ability to design environmentally sound facilities." Because knowledge about green buildings was not widespread in the U.S. at the time, the responses from A/E contractors enabled EPA to gauge the level of experience, interest and enthusiasm for the challenge of designing a green building.

Environmental Requirements in the Design Contract

General
- Energy conscious design
- Highly durable facility design–anticipate a 100-year lifespan
- Environmentally-sensitive construction materials and products
- Materials and equipment with no ozone-depleting potential
- Construction materials with no recycled content
- Aggressive recycling plan
- Radon free
- Water conserving design

Energy Conservation
- Daylighting and the optimum use of energy efficient lighting
- Life-cycle cost analysis of HVAC systems over a 30-year period
- Building Automated System (BAS) for monitoring and control

Indoor Air Quality
- Controls for outdoor and indoor sources of indoor air pollution
- Detailed site evaluation to determine impact of the site on IAQ
- Plan for operation and maintenance of HVAC equipment
- Innovative approaches to maximize ventilation efficiency
- Evaluation of building materials for potential impact on IAQ
- HVAC system that minimize impact on IAQ
- Evaluation for air cleaning devices

Make environmental goals for the facility explicit in the Request for Proposals and the Program of Requirements.

Require that the Architect and Engineer demonstrate both knowledge about and commitment to sustainable design.

"The facility shall be designed to reflect its mission. This translates into a facility that conserves energy, efficiently utilizes water, promotes effective recycling, is radon free and provides excellent indoor air quality to its occupants. The architectural and engineering design shall implement proven methods, strategies and technologies which respect and protect the environment."

–EPA Program of Requirements

Identify specific environmental design requirements in the Architect/Engineer contract.

Engage all team members in setting project goals including environmental goals.

Encourage development of environmental design goals that are overarching in nature, as well those that are specific and measurable.

EPA Campus Project Goals

Top-Tier Goals
- Functionality
- Environmental design
- Low life-cycle cost

Specific Goals
- Maintainability
- Natural light
- Communication
- Flexibility
- Close proximity/walkability
- Security

Development of the POR for the new facility presented another important opportunity to steer the project toward its environmental goals. A typical POR itemizes square footage requirements by space type and sets standards for the performance and quality of the facility. EPA expanded this approach through the inclusion of broad-based environmental design considerations, supported by detailed descriptions of features to be considered during the design process. Ultimately the entire POR, including the environmental design requirements, became part of the statement of work for the A/E contract.

In addition to the environmental design requirements captured in the POR, the A/E contract contained specific deliverables for each stage of the project that supported the development of environmentally-preferable design options. For example, there were stand-alone requirements for indoor air quality submittals, energy analysis and reports, life-cycle cost studies, site surveys, specimen tree studies, an environmental assessment and documentation of related environmental permits.

Prioritizing Environmental Goals

While EPA set forth a comprehensive list of environmental design requirements for the A/E team to meet, it also recognized that the entire design team would need to balance many competing considerations. Consequently, it was necessary to integrate environmental goals into the larger matrix of goals for the facility as a whole. The process of prioritizing would also provide an opportunity to build consensus within the group on the relative importance of the environmental goals for the project.

As a first step, EPA held a two-day design kickoff session for all design team members for the purpose of goal setting and team building. During this session, the group brainstormed a list of primary design goals for the facility. This list was then discussed extensively to develop consensus within the group and to prioritize goals. The process of developing goals as a group helped each of the members develop a sense of ownership of and commitment to these goals.

Among these overarching design goals, functionality and environmental design were identified as the most important. Cost control was not listed as a priority to be debated because it was accepted as a given. There was a fixed budget for the project and that budget could not be exceeded. In terms of functionality, the facility was being built to support the activities of a diverse group of EPA programs, and meeting the operational requirements of this work was paramount. The focus on environmental design goals for the facility was underscored when the entire team agreed that environmental design was also of primary importance. With this decision, environmental performance expectations expanded, beyond what was a collection of contract requirements for specific studies and reports documenting environmental performance, to become a core issue.

Embedding Green Goals in Conceptual Design

Concept design marks the beginning of the design process. It was during this phase that the design team began to identify and develop the ideas that organized the design. There are many issues at the core of green design that need to be addressed up front, while there is an opportunity to influence the building form and its placement and orientation on the site. These issues included:

- *limit disruption to site*
- *protect wetland areas and existing trees*
- *develop orientation and massing to maximize daylight access*
- *develop orientation and massing to maximize energy efficiency*
- *develop orientation to benefit fresh air flows*

Design Option Matrix This matrix of design options represents generic site organizing concepts on one axis and functional concepts on the other. Schemes were systematically scored, based on how they met the functional and environmental goals.

Explore and test scheme design options against stated criteria and goals.

During this phase, the A/E created multiple concept diagrams in search of options that were responsive to the functional requirements of the occupants, and that held potential for meeting environmental goals. The time invested at this stage of the design effort later proved invaluable. By systematically searching for a concept design solution that addressed all key issues, the group avoided the need to make disruptive changes as the design progressed.

Many of the defining characteristics of the selected scheme made it more responsive to the environment. For example, an "informal" composition with buildings and parking decks arranged to fit within the existing site contours was selected. This arrangement left more of the original site intact. Important natural amenities were preserved such as the knoll of trees at the high-point of the site, and the wetlands along the lake edge. This decreased site preparation costs and disruption of habitat, and reduced the need for stormwater control measures.

Many environmental design solutions provided design benefits which made the Campus more people-friendly. For example, as visitors come up the drive, they see the facility revealed one piece at a time. Because the knoll of trees was left intact at the high-point of the site, only parts of the building are visible from each vantage point. Just as the preservation of the knoll minimizes the impact on the site, the limited view of the one-million-square-foot facility minimizes the impact on the senses, which could have been overwhelming.

In addition to addressing immediate issues of the site, the selected scheme provided opportunities for future daylighting integration, energy efficiency and features that would protect indoor air quality. The central atrium which connects the office tower, cafeteria and conference center with labs and office wings, promotes the efficient use of daylight. The atrium contributes to energy efficiency by reducing the overall building surface area, while increasing access to daylight. The narrow proportion of the office buildings and the perimeter corridor in the lab buildings also increase access to daylight. To protect indoor air quality in the finished facility, the fresh air intake vents were located upwind of the laboratory exhaust stacks, based on prevailing winds.

Selection of the final scheme required the core group to prioritize and to make choices that would influence the future performance of the building. For example, the preferred concept design left long building elevations exposed to low angle afternoon sun from the west. After analyzing the pros and cons of all of the design options, the design team placed a higher priority on preserving natural site features than on providing a north-south orientation for all of the buildings. A north-south orientation is typically preferred for daylighting because it allows for controlled daylight to be shared in open office areas. For the EPA facility, the design team reasoned that the need to preserve wetlands and mature habitat areas was more important.

Seizing Early Opportunities

Verify and consolidate program requirements to optimize facility size and spatial arrangement.

Explore opportunities to design with building modules that enhance long-term flexibility.

Integrate detailed environmental requirements in the programming and concept design where possible, such as elimination of internal duct lining and planning for recycling.

As the project moved into schematic design, additional opportunities emerged to incorporate environmental features. Prior to developing a detailed design solution, the program requirements were reviewed and verified to identify ways to reduce space demands. For example, the team developed a system for locating conference rooms and copy areas in standardized locations which allowed these areas to be more easily shared. The introduction of a central library and shared support spaces further consolidated resources and reduced overall space needs.

EPA needed a flexible organizational system that could accommodate changes in research programs, and changes in the mix of labs and offices with a minimum of renovation. By placing a high priority on flexibility, EPA reduced future renovation costs, as well as associated materials use and contribution to the waste stream. The lab buildings were designed with a designated service corridor and a "flexible zone" of space parallel to the labs that could accommodate either offices or labs. Office space standards limited the number of office sizes. Offices are clustered in suites with fixed circulation patterns to enhance flexibility while ensuring the occupants access to daylight. Office buildings were designed with approximately half of the perimeter zone designated as open office areas so daylight can reach interior zones.

A number of fairly detailed environmental requirements needed to be considered at this stage as well. For example, plans for recycling were developed while the basic building organization was evolving. The conference center and cafeteria were located near the main loading dock to enhance materials handling and recycling. Building circulation routes were developed so that recyclables could be moved from individual collection areas in the lab and office buildings to the central loading dock without crossing public areas.

EPA's mandate to eliminate duct lining as a preventative measure had an impact on the building's structural and mechanical system requirements. EPA requested that the building be designed without duct linings because they can harbor mold and microbial growth, becoming a site of potential contamination that is difficult to localize and expensive to clean. Building ductwork can function well without linings, however larger ducts are required, and mechanical room layouts must be meticulously planned so sound can be attenuated. By incorporating this requirement early in design, the design progressed smoothly and the impact on cost was negligible.

Design Optimization: A Cyclical Process

As the project progressed into design development, the core design group worked systematically to "optimize" the design of the new facility. This process involved the careful evaluation of a broad range of solutions and the establishment of environmental performance benchmarks to put performance data in perspective. Advanced simulation tools were utilized to predict energy and daylighting performance. As concepts were tested, the information base for decision making expanded and some earlier decisions were revisited. As a result, the design process was a cyclical one. The willingness of the team to reconsider and revise its initial solutions to improve the design was important to the success of the project.

Evaluating Criteria/Revising Assumptions

The design criteria for the EPA campus were initially defined by the POR, EPA health and safety policies, the federal site master plan, GSA design standards, state codes and local guidelines. These criteria comprised a set of design requirements and standards identified at the outset of design. Typically such criteria are accepted as a given and design options are explored within these parameters. However, the group found that many of the most innovative solutions that reduced both cost and environmental impact, came about by challenging and reevaluating these basic design criteria. For example, they considered everything from the site area, roadway and utility requirements, to the laboratory exhaust requirements, fume hood design, office ventilation rates and lighting levels.

Encourage open dialogue within the team so that members will challenge basic assumptions as appropriate to improve the design.

When the first round of concept design schemes was developed for the EPA Campus, the design firm attempted to fit more than one million square feet of building and 2,500 parking spaces on a 64-acre site. Three stories was the preferred height for the building initially proposed because it allowed for extensive use of stairways instead of elevators to enhance communication between floors. However, evaluation indicated that all of the preliminary concepts would have profoundly altered the existing character of the site by forcing nearly complete clearing. To preserve the trees, the design group decided to increase the building height of the laboratories to five stories. The National Computer Center was relocated as a separate building on a parcel of land one-quarter of a mile north of the main campus. With the least day-to-day interaction with other EPA programs, the Computer Center was the logical choice for relocation. Still, the distance between the two facilities is an easy five-minute walk.

Even with revised massing to allow for taller buildings and a reduced footprint, much of the site area would be impacted by buildings and parking. However, the revised design parameters provided the group sufficient flexibility to preserve important natural features leaving the knoll of mature trees at the high-point of the site, the site's wetland areas and major drainage swales largely intact. Decked parking, which is rarely utilized locally, would also limit paved area.

As the site design progressed, more design features were revisited. For example, the number of parking spaces was revised from 2,500 to 1,800, the access roadway through the site was revised from four lanes to two, fire lanes were rerouted, electrical ductbanks were relocated to beneath the roadway, and curbs and gutters were eliminated in favor of grassy swales and bio-retention. Each of these decisions required the design team to challenge components of the original design criteria. Maintaining flexibility, within the constraints of schedule and cost, the group proactively searched for solutions that were cost-effective, practical and environmentally-preferable. The resulting design evolved and improved over time.

Energy Performance Benchmarks

The U.S. Department of Energy documents commercial buildings energy consumption and expenditures in the United States for the purpose of benchmarking commercial building energy performance, including office buildings, educational buildings, health care buildings and laboratories. Primary energy use characteristics examined include:

- Gross energy intensity
- Energy expenditures by fuel type

Rocky Mountain Institute (RMI) in Snowmass, Colorado, also benchmarks building energy performance including

- Gross energy intensity
- Connected interior lighting load
- Plug load, as used
- Mechanical-cooling sizing
- Whole system cooling
- Air handling intensity
  RMI's benchmark figures are provided for average, good practice and advanced practice.

American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)

- Develops standards for the design of HVAC systems
- Develops and does research to produce a set of reference books for the design of heating, refrigeration and air conditioning systems
- Organizes conventions and meetings to review new equipment and discuss innovations in the industry
- Is considered by most building codes to be the standard for design of HVAC systems

A re-evaluation of energy criteria was critical to the success of the design. Since the laboratories represented the largest portion of overall energy use, labs were given especially close scrutiny. Ensuring the safety of laboratory workers who must handle hazardous substances on a daily basis was of highest priority. Ventilation was designed to use 100% outside air and to provide 12 to 15 air changes per hour (ACH) so that any contaminants would be quickly exhausted. After intensive analysis, the design team was able to present alternatives to EPA safety officers that satisfied concerns for uncomplicated, fail-safe solutions. Safe, simple and effective energy savings were realized by linking the full closure of fume hood sashes with room light switches. The normal exhaust ventilation rate is reduced by half when research staff close fume hood sashes and turn off the lab lights as they leave for the evening.

Unfortunately, some of the design criteria that made sense when considered in isolation proved to have a ripple effect on other areas of the design that led the group to reconsider. For example, the requirement for six ACH in the office areas seemed to be beneficial in terms of indoor air quality, because it boosted the supply of fresh air. However, when energy modeling predicted that the energy consumption would be much higher than was anticipated, the group began to re-evaluate the issue. To test the validity of the air change requirement, common contaminants known to be emitted in office environments due to occupants and furnishings were "modeled" using a computer program called "Exposure."[7] This study led to a reduction of air change rates to a minimum of four ACH that maintained good indoor air quality, while improving energy efficiency.

Identifying Performance Benchmarks

During design, the design group found that identification of performance benchmarks was key to a successful multidisciplinary design dialogue. These benchmarks, which identify both "typical" and "improved" performance, allowed group members to become informed participants in a discussion that would otherwise have excluded them. For example, when architects were able to talk to electrical or mechanical engineers about energy consumption in BTU per square foot per year, they were better able to measure the value of proposed design solutions. These measures gave both specialists and non-specialists some insight into when the design was "on track," and when it could be improved.

When the design team first evaluated the energy performance of the building as designed, members were shocked to find that the design was not only inefficient, it was worse than the "standard" benchmark values. Although, the engineers were using typically energy efficient components in the building, such as outside air economizers, automated lighting controls, and high efficiency chillers, boilers, fans and motors, the full benefits were not being realized. The use of energy efficient equipment, without design refinements and systems integration, created a poor result. Because the results of the energy modeling could be compared to a set of benchmark values for typical energy performance in similar buildings, the group was alerted to the need to refine the design. This led to a series of revisions to the HVAC design that ultimately reduced energy consumption considerably.

The design team also searched for benchmark information to guide other aspects of the design. For example, the key source of benchmark information for indoor air quality was the innovative program developed for the State of Washington. By studying the details of the Washington program and analyzing its strengths and weaknesses, the group could build directly on earlier efforts and propose a series of refinements.

Using Models and Evaluation Tools

As the design group evaluated options, models and other tools that simulate future performance became essential aids to decision making. Computer and physical models were used for water quality calculations and air flow modeling in the labs. Wind tunnel testing was used to study air dispersion from the exhaust stacks outside the labs. These simulation models provided information that led to numerous design refinements.

Modeling Resources

- "Trace"[5] by the Trane Corporation for energy modeling
- "Lumen Micro"[6] and physical models for daylighting evaluation
- "Exposure"[7] an EPA program for indoor air quality

Modeling, however, can improve the environmental performance of a facility only when it informs the design process. Typically design teams employ energy modeling for sizing HVAC systems and estimating energy consumption, with little or no effort spent on testing alternatives and optimizing performance. When the energy model was used as a design tool to optimize performance, modifications made to the building design and HVAC systems improved performance from substandard, based on DOE benchmark values, to more than 40% better.

Energy design optimization began with an assessment of baseline energy loads in the lab and office components of the building. This was important because the load profiles, which were extremely different for the lab and office portions of the building, would guide the group to focus on load reduction strategies which would have the greatest impact.

As the design was further defined, the energy models required refinement. The group reviewed all of the inputs into the energy analysis program and updated them with the anticipated operating load profiles. These profiles incorporated diversity factors that captured such items as areas of the building not fully occupied at the same time, and that reflected "as-used" loads instead of "connected" loads for lighting and power. In the office areas, the as-used loads suggested energy savings from occupancy sensors, daylight dimming and computer "sleep modes." In the labs, as-used loads factored in the multiple ways the labs are used, such as partial combination of occupied and unoccupied labs and night-time airflow setback.

Search for environmental benchmarks and performance measures.

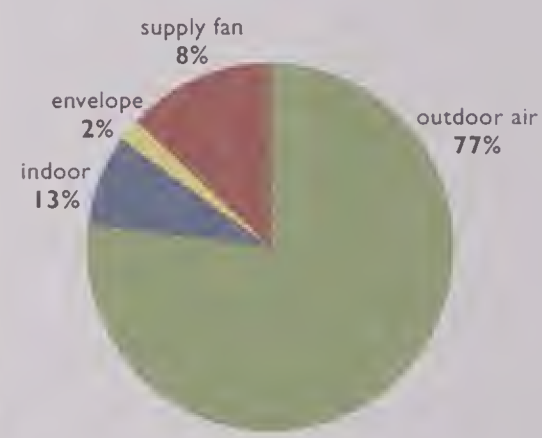
Begin energy modeling while there is sufficient time for the modeling results to inform the design process.

Carefully review engineering design criteria as standards have changed over time. Oversizing and overlighting increases energy use, first costs and operating costs.

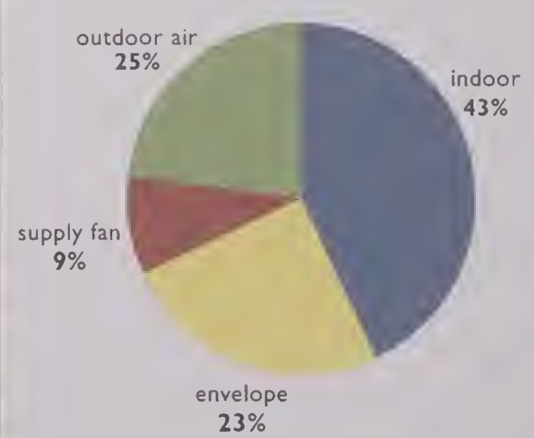
Do not rely on "rule of thumb" design.

EPA CAMPUS COMPONENT PEAK LOADS

LABORATORY
Total Load 64 MillionBtu/Hr



OFFICE
Total Load 18 Million Btu/Hr



Computer modeling also was used to create a quality assurance mechanism for indoor air quality requirements. A set of emissions thresholds was established based on what would be both acceptable and achievable, and predictive modeling was performed to confirm that emissions thresholds could be met. Based on that predictive modeling, EPA was able to assure prospective contractors that if building materials passed the emissions testing requirements, the building would also pass baseline indoor air quality testing requirements after construction was complete.

During the evolution of the new EPA Campus project, several rating systems for sustainable buildings emerged. Canada and Great Britain unveiled two of the earliest whole-building assessment tools in 1993. Along with fledgling initiatives in the U.S., the Netherlands and a handful of other countries, these early rating systems helped spark an international effort in 1998 that created the Green Building Challenge (GBC). Led by the Canadians, GBC aimed to establish international comprehensive benchmarks for environmentally-responsible building and site design from an environmental perspective. The new EPA campus was one of 30 case studies evaluated by the 14 participating countries in the prototype round of GBC.

In 1999, the U.S. Green Building Council established the Leadership in Energy and Environmental Design (LEED) rating system. LEED evaluates environmental performance from a "whole building" perspective over a building's life-cycle.

When researching environmentally preferable building materials, gather specific information about products by manufacturer, rather than generalized information about product types, whenever possible.

In the United States, the U.S. Green Building Council first established its Leadership in Energy and Environmental Design (LEED) rating system in 1999. LEED evaluates the total environmental performance of a building during all phases of its useful life, from construction through demolition. Although LEED emerged too late to be of use in designing the main facility on the EPA campus, it was applied to the redesign of the National Computer Center–a separate 100,000 square foot facility on the campus. The computer center has been designed to meet the "gold" rating criteria under LEED.

Although the international and national green building standards offer the advantage of benchmarking performance based on broad consensus, they do face some challenges. For example, it has been difficult to adjust for the local effects of climate, markets, transportation infrastructure and other locale-specific factors. Recognizing this, a number of communities and regions have brought forward their own systems. In the Research Triangle area, the Triangle J Council of Governments performed a detailed adaptation of LEED to create their own "High Performance Guidelines: Triangle Region Public Facilities" (HPG). EPA's new campus design team helped create the HPG guidelines, which were issued in 2001. The Agency will incorporate them, along with LEED, into the EPA/NIEHS child care center design-build contract.

Researching Environmental Impact

The search for physical solutions to established goals and design criteria led to supplemental research to understand the environmental impact and identify preferred approaches. In some areas, such as energy and water use, the research required proved to be minimal. However in other areas, such as building materials selection and specification, extensive research was necessary to develop resources that did not yet exist.

Civil engineers performed feasibility studies to explore cost-effective stormwater management options to effectively cleanse runoff, while minimizing site impact. The bioretention strategy that was ultimately selected was a relatively new approach relying on "pocket wetlands" filled with permeable planting soil and plantings to accelerate the natural processing of contaminants suspended in the stormwater runoff. Since this technology had never been used in North Carolina

at the time, the civil engineer had to educate regulators in North Carolina about successful bioretention systems in Maryland in order to use it on this project. This effort helped lead North Carolina officials to adopt bioretention as a Best Management Practice for stormwater treatment across the state.

Other site issues requiring research included native plantings such as wetland and wildflower species, alternatives for erosion control, permeable pavement options, performance of recycled content roadway materials and re-use of on-site materials. Specialty consultants joined the project team to develop the wetland plantings and wildflower specifications. Topics were investigated by the civil engineers, who applied skepticism, logic and common sense to test the performance of each proposed alternative material.

Environmentally preferable materials selection was a major issue requiring extensive research. Early in schematic design, the design team determined that although some sources of information were available to guide decision making about environmentally preferable products, such as the AIA's Environmental Resource Guide (ERG), manufacturer specific information regarding the environmental performance of individual products did not yet exist in any published form.

In response to this information void, the A/E voluntarily initiated an effort to gather life-cycle environmental impact information about products. With input from experts in the green building field, the A/E developed a product questionnaire that was sent to every manufacturer considered for use in the project. Response to the questionnaire was good, and the data proved useful in defining which products would be the best choices for the EPA project.


Environmentally-preferable building materials

The concept of "materials benchmarking" also added an important dimension to the research effort on environmentally preferable building materials. It led the group to explore the range of materials and products on the market, and to compare them, by developing benchmarks for materials. The research effort eventually extended beyond the products and materials to considerations of how the materials were installed, when they would be installed and, due to their potential impact on indoor air quality, how they would be maintained. This focus on IAQ led to requirements for emission testing of selected materials, so the potential impact on indoor air quality could be evaluated before materials were installed, rather than later, when the cost of removing them or mitigating their effects could be prohibitive.

In addition to requiring emissions data, the group collected IAQ specifications and related information from other projects with an indoor air focus, and prudently reviewed them to develop uncomplicated procedures to safeguard IAQ during construction. For example, instead of a 90-day "flush out" period which would have required the building to remain empty while it was ventilated prior to occupancy, the group opted for ventilation during construction. This requirement was coupled with IAQ testing to document air quality prior to occupancy, thereby ensuring that chemical vapors emitted during construction had been removed and air quality in the building met the established indoor air quality standards.

Other issues, such as the potential impact of electromagnetic fields on the health of building occupants, represented entirely new territory that required extensive research. Local issues, such as the details of the recycling infrastructure available in North Carolina, required research as this information is regionally specific and changes over time.

Green Team Core Members
Although the entire team was committed to producing an environmentally sound design, certain team members had especially critical roles in keeping the green building effort focused and on track.

EPA Project Manager
Responsible for balancing environmental goals against the pressures of meeting cost, performance and schedule requirements.

EPA Environmental Advocate
As a member of the EPA project management team, had the special role of questioning all design decisions for their environmental merits.

Environmental Scientist
As a member of the EPA research community and the original project officer for the Environmental Resources Guide, provided expert advice to the core design group on a range of pollution prevention and sustainability issues.

Indoor Air Quality Coordinator
A mechanical engineer and indoor air quality researcher for the EPA; oversaw the development of the IAQ manual and reviewed the design for indoor health impact.

Project Engineers
The EPA's lead technical staff; directed the actual implementation of green design decisions.

A/E "Green Team" Leader
As part of the lead architectural firm, had the task of assuring the environmental soundness of the complete range of architectural and engineering choices made on the project.

Greening the Team

Even though the design team understood the need to improve the environmental performance of the facility, the design process itself involved dozens of people working simultaneously on an assortment of tasks. Because of the complexity of the design and the variety of demands on all team members, the project leaders worked on greening the design team itself, to ensure that the project's environmental goals would not get lost in the process.

Unlike most organizations, EPA is fortunate to have its own in-house experts on pollution prevention, indoor air quality, energy conservation, recycling and a variety of other environmental issues. EPA invited input from these in-house experts in planning for the new facility, and the project benefited from their insights. The ultimate success of the project, however, would be determined by the extent to which EPA could engage all project team members in integrating environmental design issues into the creative decision making process.

Environmental Champions on the Team

While many design team members contributed their expertise and insight to the development of environmentally preferable solutions, EPA and the A/E each recognized that it was extremely important to have an individual with an understanding of the whole "champion" the environmental goals for the project. EPA and the A/E each designated an "environmental advocate" to guide the design internally, while also reaching out to the local sustainability network for additional support. Environmental advocates were tasked with monitoring and supporting environmental initiatives incorporated in the design. These advocates searched for information that enabled the design team to assess environmental impact, raise issues and identify strategies to consider, and facilitate the development of design solutions requiring multidisciplinary collaboration.

Local Sustainability Network

In addition to the project team that had been assembled to design the new EPA Campus, many others contributed throughout the process. A community of people involved with issues relating to sustainable design and green buildings provided crucial voluntary assistance. These independent resources in the design, academic and nonprofit communities provided valuable input. For example, volunteers linked the group with local recycling resources, identified successful demonstration projects that could serve as models, and assisted the A/E with technical information relating to emerging issues such as design for good indoor air quality and environmentally preferable materials selection.

EPA also organized a voluntary committee from within its own ranks called the Pollution Prevention Committee, to support the design effort. Meetings were held early during schematic design, which led to the creation of an extensive list of green design strategies to be considered. Some of the members of this group remained involved as advisors to EPA to assist during design reviews. The Pollution Prevention Committee was a great mechanism for broadening involvement and generating ideas that spanned many disciplines.

Integrated Team Approach

Recognizing that optimal sustainable design strategies rely on synergy achieved when one solution addresses multiple objectives, the design team collaborated by physically working together. Work sessions and design reviews included EPA, the A/E and its consultants. Though this collaboration required the group to spend more time in meetings, the design process as a whole became more efficient.

Design integration leads to more optimal solutions, reduces backtracking and relieves the need to spend extensive amounts of time "coordinating" the various disciplines after the fact.

For example, architects, interior designers, mechanical/electrical/plumbing (MEP) engineers, civil engineers and others needed to collaborate closely to create a site plan and building massing that would balance a diverse set of functional and environmental goals. Interior designers provided input on site orientation and building massing based on how it would impact future interior planning and daylight access. MEP and civil engineers integrated issues that might otherwise have been deemed "secondary," related to site infrastructure, underground utilities and fire lanes. The "integrated" design scheme worked within the existing site contours, allowing large portions of the site to remain forested and preserved wetland areas.

Another benefit of the integrated approach was that non-experts included in design discussions could offer a fresh perspective. For example, when water quality ponds emerged as the strategy of choice for stormwater treatment because of greater effectiveness, lower cost and use of natural methods to purify the water, the engineers did not focus on the impact that the pond would have on the landscape. Though the ponds were not large, the grading necessary to direct runoff toward them would have altered much of the landscape and required tree clearing for vast portions of the site. In one of the regularly scheduled design meetings, a nontechnical person asked the obvious question: "Look how many trees are being cut down to 'save the environment' isn't there a better way?" This fresh perspective led to a reinvestigation of options and to the less disruptive "pocket wetland" bioretention method that was adopted.

Maintaining the Commitment

The challenge for any project, regardless of the investment of energy into careful project planning and team building, is the follow through. The effort spent defining goals, evaluating options and performing analysis to identify the best integrated design solution can all be lost in one misdirected value engineering session. Likewise, for a successful project, the construction detailing and specifications must be developed to support the environmental design strategies. Performance tracking, green value engineering and partnering for construction were other strategies that proved to be instrumental in maintaining a focus on the environmental goals for the facility.

Following Through on the Details

Specifications and construction details are "conventional" by their very nature, because design professionals protect themselves from risk by relying on methods that have worked successfully in the past. Specifications and details are also heavily influenced by third parties. Material suppliers can limit or revoke warranties if manufacturers' recommendations are not followed. Equally true, however, is the fact that specifications and construction details continuously evolve in response to innovations and changing requirements. The challenge was to direct review toward more sustainable solutions. Each modification to conventional practice required extensive investigation to ensure that no element of building performance would be compromised.

Specifications not only document choices about which materials are to be used, but also provide information about secondary materials such as adhesives and finishes. In some cases, options were provided and the specifier simply needed to

Identify environmental champions on both the owner and the A/E teams.

Identify local groups dedicated to sustainable design that can provide information or design assistance.

Clearly describe performance requirements in the specifications, and require submittals to certify that requirements have been met.

Review the specifications with an eye to making environmental performance improvements wherever possible.

Use Division One of the specifications to summarize atypical environmental performance requirements.

When developing specifications, consider the environmental and IAQ impact of adhesives and finishes, as well as the specific materials.

choose the option that was environmentally-preferable. For example, nearly every flooring manufacturer either makes a zero-VOC adhesive, or has approved one, though they may still carry the old higher-solvent formulations. In other cases, such as the high performance finishes required in the laboratory environment, research was needed to identify alternatives to finishes that are standard in the industry, but factory applied.

The team also anticipated challenges that might occur during construction. By painstakingly defining environmental performance requirements and the submittals required, alternate products proposed for substitution were screened for environmental performance.

Division One of the contract specifications was developed specifically to highlight unusual environmental requirements. Division One of the specifications contains the project General Conditions, key non-technical requirements for the prime and all subcontractors. By summarizing environmental requirements in this initial section as well as in the technical provisions that follow, EPA was assured that the contractor understood the environmental requirements from a "big picture" perspective. A new section, *Environmental Impact of Materials*, was created to diminish the possibility that either contractors or subcontractors could misunderstand environmental requirements. Cross-referencing between this section and the individual specification sections provided clear and consistent documentation of environmental requirements.

Unique specification sections were developed for Division One to clarify atypical construction procedures. At the beginning of the project manual, a section entitled *Environmental Requirements*, simply describes EPA's environmental goals for the project. The section begins with the following statement: "It is the goal of the EPA to integrate the Agency's mission into this project as much as feasible and practical; i.e., to construct a green building." Other Division One sections include *Testing for Indoor Air Quality, Baseline IAQ and Materials; Sequence of Installation Finishes; and Waste Material Management and Recycling.* Detailed commissioning requirements are located in the mechanical and electrical sections to ensure that the building will operate properly, and that energy savings will be realized.

Track the development of contract documents thoroughly to ensure successful inclusion of environmental design features.

Tracking Environmental Performance

The core design group found that mechanisms to track environmental performance were especially essential in the later phases of the project. The number of decisions made on a daily basis would multiply as the project moved into the final stages of design. Tracking environmental design strategies helped highlight the "non-standard" features requiring special attention.

The tracking process involved ongoing design review as well as periodic reporting. A detailed report issued at the end of Design Development itemized all environmental features incorporated into the design. The report was organized by design topics: Site Design, Energy Conservation, Water Conservation, Building Materials, Indoor Air Quality and Waste Management. The design strategies suggested by EPA's Pollution Prevention Committee were tracked in the report as well as additional issues identified along the way. The report contained an energy budget, which predicted future energy costs through computer modeling, and a description of all of the energy conserving features of the design. This report, updated and reissued at key milestones, led to a series of itemized checklists that were distributed to project team members from each discipline.

Summary of VE cost savings during the Design Development phase

ITEM	STRATEGY	ENVIRONMENTAL BENEFIT	CONSTRUCTION COST SAVINGS	LIFE CYCLE COST IMPACT
Roadways and Utility Lines	Depart from federal site master plan requirements for 4–lane roads plus utility easements; design 2–lane roads and bury electrical and communication lines under the road	Greatly decreased road and utility footprint – preserving site woodlands and wetlands	$2 million	Less maintenance and repair cost
Stormwater	Replace curb and gutter and oil–grit separators with grassy swales, water quality ponds and bioretention	Improved on–site treatment of stormwater	$500,000	No increase or decrease
Atrium Skylight	Revise from all glass to one third glass, one third insulated translucent panels and one third solid	Improved energy performance and indoor environment–thermal comfort and light quality	$500,000	Lower energy cost ($50,000 / year)
Laboratory Exhaust Hoods	Install 250 specialized fume hoods and exhaust systems that reduce total air flow demand by 50% and eliminate dozens of fans	Prevents consumption of large qualities of conditioned air	$1.5 million	Lower energy cost ($1 million / year)

While the checklists served as a reminder of the decisions that had been agreed upon, design reviews were also necessary to correct misunderstandings that would emerge. For example, at one point late in the construction documentation phase, it was discovered that a lighting designer had introduced a large quantity of inefficient incandescent light sources in the entry lobby of the main facility to make the space feel "warmer." The design team had worked hard to develop a pleasing, energy efficient, lighting scheme. When it was brought to the group's attention, the interior designers clarified that although fluorescent lighting may have seemed unconventional in a lobby space in the past, color rendition of compact fluorescent lamps had improved tremendously. If necessary, the coloration of the space would be fine-tuned by adjusting the stain on the wood panels and the paint on the walls. As a result, the construction documents were changed and the fluorescent lighting was maintained.

Using Green Value Engineering

Throughout the design process, the issue of cost, and particularly the cost of green design strategies, was scrutinized judiciously. In addition to ongoing analysis of options by the cost consultant and a member of the core design group, EPA chose to engage in focused Value Engineering (VE) reviews. VE is often seen as the enemy of good design in general and green design in particular. At its best however, VE is not merely a cost-cutting exercise, but a review process to enhance "value." EPA used the VE process to balance cost, function and environmental performance when considering options.

The VE process became especially important when extraordinary challenges were introduced by the political process that is unique to the design of a large government facility. When the U.S. Senate was considering appropriations for the new facility, they asked EPA to review the project again to see if the total cost could be significantly reduced. This challenged VE participants to produce creative cost reductions without compromising functionality, reducing program area or compromising environmental goals. The core design group not only reduced the total project cost by approximately $30 million, but the VE cost-reduction exercise produced a greener building.

Encourage the VE process to balance cost, function and environmental performance.

Include designers and environmental advocates on the VE review team.

Encourage the development of VE proposals by interdisciplinary teams to promote integrated design solutions.

One reason the VE sessions were so successful was that the inclusive process allowed for informed, interdisciplinary brainstorming to occur. Led by a special VE group of the Army Corps of Engineers, the design team, participated in the brainstorming of VE proposals, ensuring that the finer points of the design were not overlooked. Together, we worked to save money retain the functional needs and keep the project green all at once.

Given the tremendous pressure to reduce the first costs of the design, it is surprising that many of the environmental features that required a first-cost investment remained. Fortunately, the team recognized the importance of looking at the project and the budget as a whole, not simply line by line. While energy and water conservation, and materials minimization would be economically justifiable, either in terms of first costs or life-cycle costs, other environmentally beneficial strategies would not provide an immediate dollar payback. By considering value broadly and making design trade-offs in other areas, EPA justified design decisions that might never have survived purely economic scrutiny, such as the use of certified sustainably-harvested wood.

The VE modifications are interesting to study both for what they contain as well as for what they do not contain. Difficult choices were made, and the trade-offs reflect the values of EPA. For example, EPA replaced the slate flooring in the public areas with ceramic tile, but chose not to delete humidification from the office buildings, because it would contribute to occupant comfort over the long term. Rather than delete occupancy sensors, which save energy by turning off lights when people leave their offices, EPA decided to omit doors on suite entryways. Rather than use wood paneling that was not from independently-certified sustainable sources, the group chose to reduce the amount of wood paneling, using it in small quantities in public areas. Sidelights, which bring daylight into the interior closed offices, were also maintained by making similar tradeoffs.

One of the most important VE issues involved the decision to keep structured parking rather than all surface parking. This decision alone represented several million dollars that might have been spent on the facility, however, it emphasized the undeterred commitment to value the site environment. EPA felt strongly that use of all deck parking, which would have required the clearing of an additional 15 acres of land, disrupted wetland areas and existing drainage patterns, and eliminated nearly all tree coverage on the site, was not acceptable. To compensate for the cost impact of the decision, the quantity of on-site parking was reduced by 25%, and EPA made a strong commitment to create incentives for employees to use alternative transportation.

Educate all members of the construction team about the project environmental goals.

Preparing for Construction

Recognizing the size and complexity of the new campus, EPA selected the GSA as construction manager for the project, due to their expertise with large-scale construction.

Encourage contractor to join the project as a partner, and contribute to development of creative, environmental design solutions during the construction phase.

Unfortunately, when the construction procurement was initially advertised and competitively bid, the bid prices exceeded the project budget. This raised the question, "Did the bids come in higher because of the environmental requirements?"

EPA and GSA invited the bidders to comment on what could be done to reduce the cost of the project. It is interesting to note that only two of the many comments received were related to environmental features of the design. One contractor commented that the "wet sponge method" for finishing drywall, which

was specified to protect construction workers and the building from silica dust released into the air with dry sanding, added 50% to the cost of the gypsum board installation. In the end, a conventional gypsum finishing method was permitted, since a requirement by the contractor to seal off ductwork during gypsum finishing, and to clean the ductwork prior to building acceptance would already ensure dust-free ventilation systems. A phased installation sequence would also keep carpet out of work areas until dusty wallboard work was complete.

The other comment that EPA received from the contractors related to the detailed emissions testing of material assemblies. Originally all materials that would have a potential impact on IAQ were to be tested. It was expected that the cost of testing, an extremely small portion of overall cost, would be borne by manufacturers eager to participate in the project. Faced with budget concerns, and the fear expressed by contractors that the procedure could get lengthy and complicated, the specification was revised on the basis of relative contribution to the office air zones. Four assemblies which presented the greatest exposed surface areas were tested for emission potential–wall paint, acoustical ceiling tile, spray-on fireproofing and carpet. This change reduced the paperwork burden and much of the perceived risk for contractors while allowing EPA to retain stringent environmental constraints on the materials used in the project.

Though the economic analysis and information from contractors indicated otherwise, there was tremendous temptation to remove many of the green specifications from the project because of the concern that they were related to the cost overrun. Fortunately the group had addressed cost issues throughout the design process, and the research on the cost and availability of environmentally-preferable materials was well documented. Except for the two issues previously noted, the green specification was maintained in the next set of construction documents.

The project's actual bid price compares favorably with government industry and academic facilities of similar scope. The design team's research efforts and practical approach had kept the cost of the green design well within industry standards.

When GSA selected a general contractor, a new member and potential collaborator joined the team. At this time, the A/E introduced a construction administration team that contained some new players, though the environmental advocate roles were maintained.

The final preparatory phase prior to construction involved a partnering session to focus the newly formed construction team on working together to enhance safety, quality and environmental performance. The session included a presentation of the environmental goals for the facility and a viewing of a training video on environmentally friendly construction practices created especially for this project. The video was required viewing for every construction worker on the site to teach the construction team about environmentally-sensitive practices during construction and to explain its importance. The expectation was that construction workers and managers, inspired by the goals of the project, would be motivated to become willing partners in the creation of an environmentally-friendly construction site. The signed partnering charter included a commitment by all parties to environmental, safety and quality goals.

Conclusion

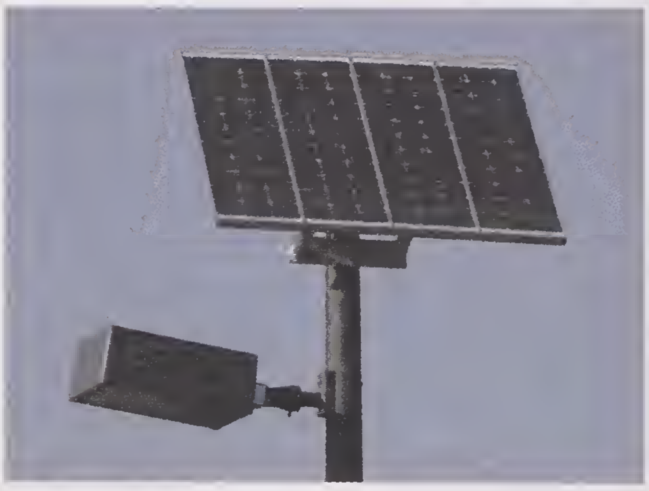
When EPA and its partners began the long process of designing and constructing this project, sustainable buildings were in their infancy. Reference material for architects, engineers and builders was extremely limited, and few green building case studies had been documented. The design team did not let this stand in the way of its goal.

In the absence of a full set of tools and resources, the design team recognized that creating a sustainable campus would require a new process based on a new way of thinking. The commitment to question, research and evaluate every possible component of the building process was the key to making their goal a reality. Early on, the group embraced the commitment to a sustainable process and upheld it throughout design and construction.

The success of this project was based on the strong emphasis on environmental quality that has traditionally been placed only on cost and functional performance. Just as our focus on cost helps us realize better value in everyday life, the environmental consciousness of the EPA project has yielded an improved value in the construction of the campus. This represents a shift in thinking that is much more significant than any individual tool or reference material.

During the past decade, there have been huge advances in sustainable building. Through this project and others, the building industry is learning about sustainability and incorporating it into its work. Advancements are likely and it is EPA's challenge to stay abreast of new technologies and practices as they relate to managing and operating the Campus. The design team recognized this need and left room for improvements to be made. For example, heat recovery units for the lab exhaust system were not justified by meager energy savings, but space was accommodated in the laboratory penthouses so they could be added in the future if costs become competitive.

EPA has continued to set aggressive goals for sustainability, seek fresh ideas, gauge progress and make improvements. Without the momentum of construction it might be hard to maintain this focus, so the EPA Campus team has taken a few steps to avoid complacency. To unearth new innovations, an advisory committee now focuses on sustainable building and site operations. EPA has also worked out an agreement with the local power company to install solar-powered street lights, and has arranged for two local bus systems to pick up and drop off at the front door of the Campus. With construction complete, EPA's goal will be to operate the facility in an environmentally responsible manner.



With a dedication to continual learning and a commitment to constant improvement throughout the life of this facility, EPA will continue to advance sustainable building concepts and preserve the strong educational value of the campus.

DESIGN ISSUES DISCUSSION

Site Design

While the challenges of environmentally-sensitive site design for projects located in urban, suburban or rural settings vary and the solutions can differ, the overall issues are largely the same. These issues involve disruption and displacement of wildlife habitat, increased erosion, diminished ground water recharge and threats to the water quality of surface water bodies and aquifers.

Minimize Site Disruption

The issue for the EPA in RTP was not where to build its new facility, but how to best build on its land. The site, an undeveloped tract of abandoned farm land, had been deeded to the federal government in 1968 for federal environmental research facilities. Site features include a man-made lake, a wooded knoll, a pine and hardwood forest and wetlands. The site's elevation varies considerably and the rolling topography creates distinct ridges and valleys that drain into the lake. Low-lying areas and drainage swales support mature hardwoods and wetlands, which contrast with a densely wooded knoll, sixty feet higher at the site's center.

The primary challenge of the site design for the EPA Campus was to accommodate the needs of the building and sitework within the existing ecosystem with a minimum of disruption. After a thorough evaluation of the site's natural features, topography and hydrological systems, the EPA project team developed a site plan that would reduce large scale disruptions and protect some of the site's unique natural assets. The plan limited the size of the development footprint and controlled other site components such as underground utility lines, and construction grading and staging areas.

Following conceptual design, a decision was made to expand the 64-acre parcel of land originally set aside for the project to 133 acres. This did not require the acquisition of additional land since the original site, deeded to the government in 1968, was approximately 500 acres. Half of the land had been developed by the National Institute of Environmental Health Sciences with the other half reserved for EPA. At the same time, the design was changed from a three-story campus to a series of three- to six-story buildings to minimize the total building footprint.

The final design for the EPA Campus organized laboratory and office buildings and the accompanying site infrastructure within existing site contours. This reduced the building's impact on forest, wetlands, wildlife habitats and drainage patterns, by greatly reducing the need for regrading at the building perimeter. The high point, a wooded knoll at the center of the site, was preserved intact and was highlighted by the entry drive that encircles it. The use of structured parking decreased the overall size of the development footprint. In addition, EPA's commitment to carpooling and alternative means of transportation reduced the parking requirement by hundreds of spaces. Site utilities and emergency access lanes were carefully routed to be near the building and within areas that were already disrupted for roadway construction.

Key Issues to Consider

- Rehabilitate an existing site or redevelop an urban infill site, when possible
- Develop compact massing to preserve open space
- Preserve natural vegetation, water sources and topography
- Preserve and enhance wildlife habitat
- Consider use of pervious paving materials to minimize impervious coverage of the site
- Consult with site analysis drawings and tree surveys before beginning design
- Plan to save trees during and after construction

EPA site before construction

Statistics
Site: 133 acres
Building: 10.05 acres
Paved Areas: 16.9 acres

100% surface parking study

Site plan of final parking design with both structured and surface parking

Structured Parking

Parking decks and public transportation are two approaches for preserving green space and limiting dependence on the automobile. Two factors typically drive the selection of structured parking: construction costs and space limitations. The unit cost for structured parking is typically about four times the unit cost for surface parking. In addition, land is readily available in RTP and the zoning codes permit nearly unrestricted use for parking. Consequently, the project team's specification of structured parking represented a departure from standard practice in the RTP area.

However, a study of an "all-surface" parking alternative revealed that the cost of surface parking on the site would be a little higher than average because of the need for additional grading, retaining walls and stormwater management. The all-surface parking scheme would have covered an additional eight acres, requiring greater forest clearing and disrupting drainage patterns and wetlands. Though the all-surface parking scheme would save several million dollars, EPA opted for the more compact design, which would use a mix of surface and structured parking.

To offset some of these costs, EPA reduced the overall parking requirements by about 25 percent. To minimize the impact of reduced parking on employees, EPA is creating incentives for carpooling and is exploring alternative means of transportation. Easy access to public transit systems has also been provided. The decked parking actually provided better service to employees and visitors by bringing more parking closer to the buildings.

Fire Lanes

Fire lanes are required by code to provide fire truck access to all parts of the Campus' buildings. While essential for safety, fire lanes have the potential to wreak havoc on tree-preservation strategies. These access lanes generally require a clear, level and permanently unobstructed zone that is a minimum of 36 feet wide and 10 feet away from the building. If the fire lane is not a continuous loop, turnaround areas that are at least 100 feet in diameter must be provided.
To reduce the impact, the EPA project team worked closely with the local fire marshal to develop a plan to meet all requirements and minimize site disruption.

The plan calls for the development of roadways on the entry side of the site for fire truck access and a grass paving system for most of the fire lanes to the west, so that total impervious surface on site could be minimized.

Erosion Control

Reducing the loss of valuable topsoil was particularly important on the EPA site, not only to protect on-site streams but also the man-made lake from sedimentation. Developed in accordance with North Carolina Sedimentation Pollution Control requirements, EPA's erosion control plan included specifications to guide construction and maintenance of the erosion control features. Plan measures included tree protection devices, temporary perimeter diversions and sediment traps or basins, and silt curtains across lake inlets. The plan also specified dust control measures and required the stabilization of disturbed areas with temporary seeding. Topsoil removed from the site and stockpiled for reuse was temporarily seeded.

Site planners and civil engineers worked closely with the rest of the project team to develop an erosion control plan that is integrated with the design, and meets the overall environmental goals for the project. When details of EPA's erosion control plan were reviewed, it was determined that the standard list of materials approved by the state for stabilization of temporary coverage included some materials, such as asphaltic tackifier, that were undesirable from an environmental perspective. The specification was revised to allow only biodegradable, nontoxic substances to be used for soil stabilization, and to require the use of 100% recycled content hydromulch in the seeding around all Campus buildings.

Loop Road

The 1970 U.S. Public Health Service Research Park Master Plan, that addressed the entire 511-acre campus in RTP, specified a four-lane loop road to provide access to all buildings. The plan also identified an underground utility loop fully accessible for maintenance and repairs, built outside the roadways on both sides. To implement the master plan's design would have required clearing a 235-foot wide swath of trees about one mile long.

View of existing lake on the EPA /NIEHS site prior to construction

Site plan with four-lane road

Site plan with two-lane road

The largest oak tree on site is 12 feet in circumference.

The project team questioned the master plan requirements for the four-lane loop road as being both extremely costly and disruptive to the natural environment. Detailed traffic studies demonstrated that a two-lane road would be more than adequate to handle traffic flows. Based on both the cost and negative environmental impact of the four-lane road, the design was changed to include a two-lane road. Electrical and communication lines were moved under the roadway, further reducing the required clearing. Combined with land-conserving parking decks and tight construction clearing limits, the roadway redesign required less than half the amount of clearing, saving 25 acres of forest. The narrowed roads cost $1.6 million less–which offset much of the cost premium for decked parking.

Preservation and Enhancement of Wetland Areas

The existing site drains into a man-made lake, with more than nine acres of wetland areas occurring in the zone where the drainage swales meet the lake. To protect these wetlands, a buffer zone approximately 100 feet wide was established along the lake edge. No development was allowed in this buffer zone except for a network of walking and jogging trails.

One exception was necessary at the site's northern edge, where the site narrows. Here, the new loop road disturbed 0.13-acre of wetland area. To compensate for the lost wetlands, the project team chose to enlarge a 0.024-acre wetland to almost an acre in size. The enlargement created almost seven times more wetlands than were lost. It also provides a "naturalist garden" for the Campus.

Specimen Tree Study

A tree survey is an important first step when designing and building on a wooded site, however a survey alone is not sufficient. An integrated, "green" approach to siting requires the entire project team, civil engineers as well as architects, to consider specimen trees during the formative stages of scheme design. In this case, the schematic design for the roadway to the EPA Campus was completed before the tree survey was consulted, and the result was a design in which the main entry drive for the facility would have destroyed many of the most mature trees on the site.

In the end, however, the roads were redesigned to save several large oak trees. The preserved area now forms a natural gateway to the site and serves as a living reminder of the homesteads that stood there in the early part of the 20th century. The "near miss" with the oak trees had a surprising side effect, making these historic trees a symbol to the EPA project team of the importance of designing with nature.

Water Quality

All construction sites impact their watersheds, affecting both surface and subsurface water quality. Water contaminants from a typical building site include nutrients from fertilizers and toxic chemicals, pesticides used on landscaped areas, hydrocarbons from roadways and parking lots and sediment from soil erosion.

The EPA Campus has been developed to protect water quality. The man-made lake and wetland areas on the site act as pre-existing water quality features to control runoff and filter contaminants. These have been supplemented by a new water quality pond and ten biofiltration sites to provide stormwater retention, sediment collection and filtration before water is released downstream to Burden's Creek. Even though the EPA Campus only affects a small portion of the 511-acre watershed, the use of highly effective stormwater runoff control measures reduces downstream impacts within the basin.

Pollution Prevention Strategies

Many of the design decisions for the new EPA Campus, contribute to improved water quality through pollution prevention. These pollution prevention strategies include the use of low maintenance landscaping that relies on native and adapted species and reduces the need for fertilizers and pesticides. Incentives for carpooling and mass transit coupled with reductions in parking will lower traffic density, thereby reducing airborne hydrocarbon and particulate contaminants. Parking decks, grass paving for emergency access roads, and mulch pathways for nature trails further reduce the total amount of impervious surface and help reduce runoff. The facility also meets all National Pollutant Discharge Elimination System (NPDES) permitting requirements.

Erosion Control

Erosion control for the EPA Campus was designed according to North Carolina requirements, which require measures including sediment traps and silt fences to retain coarse sediment during construction, operations and maintenance. These measures are essential to protect the on-site lake from sedimentation. As enhancements to the State's mandates, additional filtration measures were added to trap fine clay particles. During construction, an experimental gypsum treatment process was used periodically to accelerate settling of the clay, improving the effectiveness of the sediment ponds.

Water Pretreatment Options

Runoff from roadway and parking areas contains hydrocarbon and particulate contaminants as well as heavy metals such as mercury. A common stormwater treatment method is to capture these contaminants in a physical device such as an oil-grit separator to "pre-treat" the water before it leaves the site. Oil-grit separators were considered for the EPA Campus but ultimately not selected because other strategies were discovered with higher contaminant removal efficiency, lower cost and lower maintenance requirements.

The strategy preferred by the project team was one in which concentrated flows are collected and treated in small bioretention areas. These areas are distributed around the site in ten different locations. In the collection step, grassy swales at the edges of paved areas are used instead of curbs and gutters to channel the water to the bioretention areas. These swales encourage runoff to "sheet flow" over vegetated areas, naturally filtering contaminants suspended in the runoff as the water passes through the vegetation and percolates through the soil. Larger water quality ponds at the northern and southern ends of the site serve as additional cleansing devices for areas not served by bioretention ponds. These bioretention facilities and water quality ponds were also designed as aesthetic enhancements to the site.

The realities of the site, however, required that the use of swales be balanced with other priorities. Curbs and gutters were still used in small areas where absolutely necessary to prevent extensive tree clearing or to control traffic.

The bioretention areas use subsurface compost and plantings to accelerate the filtering of contaminants, while water quality ponds retain stormwater in constructed ponds filled with wetland plantings that cleanse the water. Water quality ponds were not selected as the primary solution because they require a larger amount of tree clearing than the smaller bioretention areas, which can be tucked into areas already being cleared for roadway construction. The water quality pond, however, can accommodate a larger quantity of runoff. The pond at the south end of the site has a storage capacity of one-half acre-feet of water (160,000 gallons).

Key Issues to Consider

- Work with natural drainage systems
- Minimize the use of impervious paved surfaces
- Plan on-site stormwater retention where natural filtration is insufficient
- Protect existing water sources from soil erosion or other sources of contamination
- Maximize use of passive and natural methods for treating stormwater, such as sheet flow across vegetated areas and bioretention

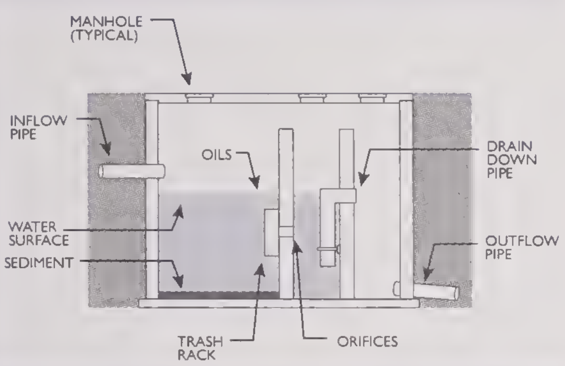
What is an NPDES Permit?

Because sediment is recognized as a significant pollutant that results from construction activity, NPDES permits are required for all construction sites larger than five acres in size. To comply with permitting requirements, erosion controls are required prior to and during construction, and stormwater management practices are required after construction.

What is Non-Point Source Water Pollution?

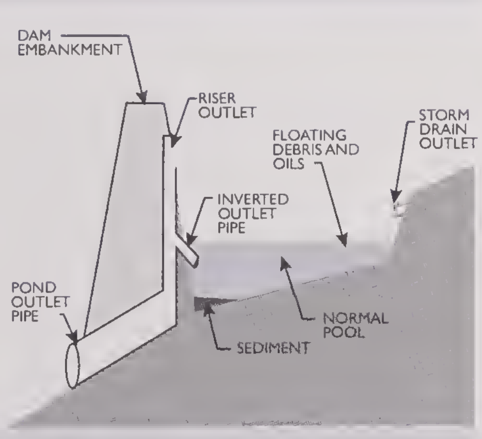
Any source of water pollution or pollutants not associated with a discrete conveyance, including runoff from fields, forest lands, mining, construction activity and saltwater intrusion.

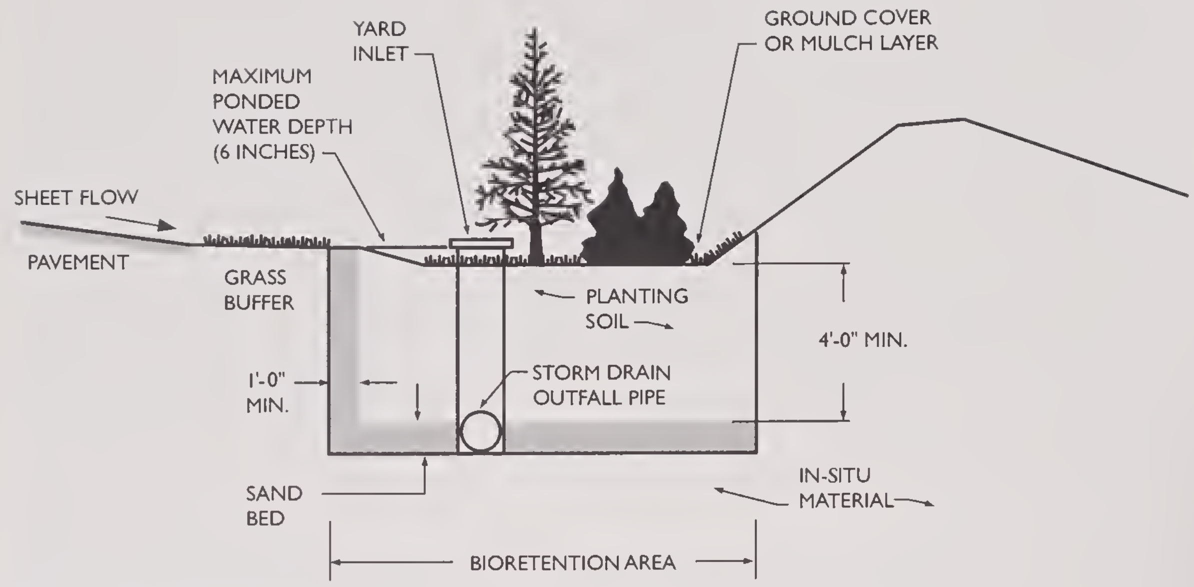
Oil-Grit Separator
A three–chamber underground structure which uses gravity to separate the grit and oils from the water. The grit and sediment in the runoff settle to the bottom of the first chamber of an oil-grit separator. In the second chamber, the oils rise to the top and are trapped in the chamber by an inverted pipe, which draws water from the bottom of the chamber. The third chamber then discharges the "cleaned" runoff.



Bioretention
A depressed, heavily vegetated area using plants and soils to remove pollutants from stormwater runoff. Various physical and biological processes including absorption, transpiration, filtration and decomposition occur in the root zone to improve water quality (see Bioretention diagram).

Water Quality Pond
A permanent pool of water used for treating stormwater runoff. Water quality is achieved by gravitational settling, algal settling, wetland plant uptake and bacterial decomposition.





Bioretention diagram

Landscaping

Low maintenance landscaping provides one of the most cost-effective opportunities for sustainable design. By choosing plants tolerant of native soils, climate and water availability, irrigation systems are simplified or eliminated and the associated maintenance and irrigation costs are reduced.

The landscape plantings selected for the EPA Campus represent a cross section of plants that are either native or adapted to the region, and drought tolerant. Plant health will be maintained through the use of compost and organic mulches prepared on site.

Low-Maintenance Landscaping

The new plantings for the EPA Campus are either native species or species that can survive the local climate, soils and water availability. This minimizes the need for fertilizers, pesticides and irrigation. Because of this reliance on native and adapted plantings, a "quick coupler" irrigation system has been provided as a low-cost and appropriate alternative to a fully automatic irrigation system. The quick coupler can be connected to hose bibs at intervals throughout the site to irrigate new plants during their period of establishment and to assist during periods of extreme drought.

An exception to this approach was made in the main building entry plaza for plantings in the raised planter beds. These planters provide a non-permanent landscape that may include some "exotics." Accent plantings on the main entry plaza will be irrigated with an automated drip irrigation system. The drip irrigation system provides a highly water-efficient solution for these small, localized areas which will require irrigation.

Grasses and Wildflowers

Instead of using traditional turf grass, the 15 acres of land along the road will be planted with wildflowers and native warm season grasses. These wildflowers and grasses are available in five palettes of color and species. A detailed wildflower specification identifies species and quantities of seed for each palette, with a schedule that will establish a permanent colony over a three-year period. The specification includes seeding directions for spring and fall plantings, environmentally acceptable herbicides and biodegradable soil retention blankets.

This low-maintenance alternative will add diversity and attract wildlife while requiring mowing with a "bush hog" only once a year to control woody vegetation.

Wetland Plantings

A total of 0.154 acres of wetland area will be disturbed by construction: 0.13 acres from an unavoidable road cut and 0.024 acres when wetland area is converted into a larger wetland pond. When complete, the new pond plus the remediated wetland areas will comprise almost an acre of new wetlands. Once the wetland pond has been established, an underground transfer pipe will allow water to flow to the lake and back, controlling water levels in the pond. It is anticipated that the pond will need minimal annual maintenance to control forest succession and weedy overgrowth.

Just as the undisturbed forested knoll at the center of the entry drive creates a public identity for the facility, the wetland pond on the lake side of the site will form a human-scaled, private sanctuary. The small pond with a naturalist garden of wetland plantings will underscore the value of wetland environments.

Composting

Plant health can be greatly improved by the use of compost and organic mulches. The project team made plans to incorporate these resources throughout the life of the facility.

Wildflowers attract wildlife

The specifications stipulated that during construction, land that required clearing would first be logged for valuable timber, and then the remaining debris would be shredded in a tub grinder to create mulch for future use on the site. This is in contrast to the prevailing practices in this region, where it is typical for landscape scrap to be piled high and burned. Mulch stockpiled on site has been aged for use in finish landscaping. Some of the mulch has been mixed

Key Issues to Consider

- Select plantings with minimal irrigation, fertilization and pesticide needs
- Plant native species
- Protect and enhance wildlife habitat
- Compost food waste and landscaping debris on site
- Consider alternatives to turf grass where appropriate

Representative Plant Mix

Wildflowers
Black-eyed Susan, Purple Coneflower, California Ox-eye Daisy, Yellow Cosmos, Toadflax, Cosmos, California Poppy, Tickseed, Moss Verbena, Perennial Lupine

Tall Grasses
Indian Grass, Little Bluestem Purpletop, Sideoats Grama, Blue Grama

Wetland Plantings
Arrow Arum, Lizard Tail, Tussock Sedge, Sweetflag, Blue Flag Iris

Wetland Meadow Plantings
Broomsedge, New York Aster, Switch Grass, Little Blue Stem

Wetland plants

Benefits of Composting

- Transportation of organic waste from landscaping and food preparation of the site is eliminated or minimized
- Biodegradable waste is not stored in landfills, where it would be mixed with inorganic and often toxic wastes and prevented from biodegrading
- A renewable source of organic fertilizer for landscaping is created on site
- Plant fertilizers need not be transported to the site

Key Issues to Consider

- Optimize building insulation
- Optimize building glazing
- Incorporate exterior shading and sun control
- Evaluate impact of interior sunshading
- Minimize air infiltration
- Provide adequate air barrier and vapor retarder
- Minimize unintentional or uncontrolled thermal bridges
- Use light-colored roofing

directly into the topsoil, where the decomposed material will aerate and amend the soil for more productive plant growth. Cafeteria waste at the Campus is also composted and used for landscaping on site.

Building Envelope

Improvements to the building envelope typically provide the first line of defense in energy-efficient design strategies. Sunshading, insulation, a tight building envelope that limits infiltration and thermal bridging, and high performance glass all reduce unwanted heat gain or loss. "Optimizing" the design of the building envelope refers to a process that systematically evaluates options to find the best combination of strategies that will cost-effectively improve performance.

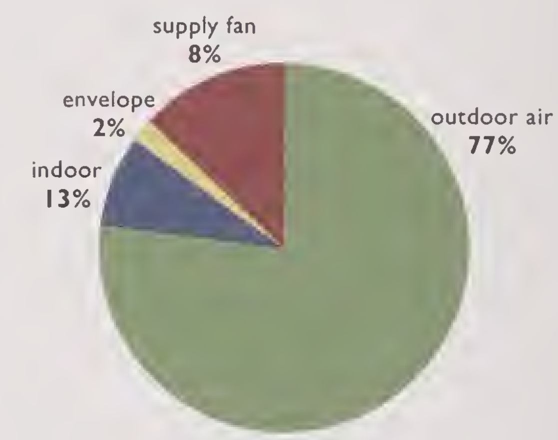
Evaluation of Building Loads

Before energy design strategies can be explored, an understanding of the building's most significant energy requirements should be developed. Major components of the EPA facility energy load were ranked by building type (see accompanying pie charts). These components included outside air for ventilation, internal loads generated by occupants, lights and equipment; energy for supply air fans; and heat loss and gain through the building envelope.

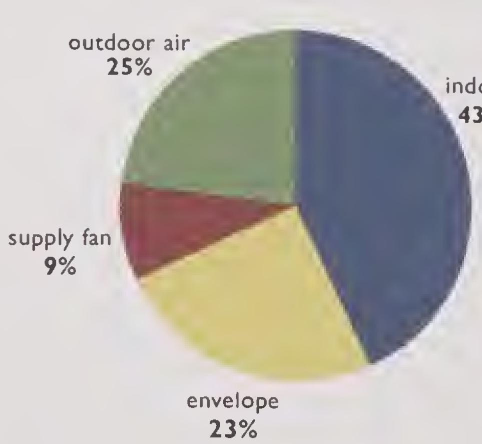
These initial load profiles guided the project team as they sought design strategies with the greatest benefit. For the new EPA Campus, high ventilation requirements in the laboratories, and high internal loads in the offices lessen the relative impact of the building envelope on overall energy use. The relative importance of the building envelope in terms of overall energy use is also much greater for the office buildings than for the laboratory buildings. For example, office buildings attribute 23 percent of peak energy load to the building envelope and the labs only attribute 2 percent. This indicates that improvements in the building envelope of the office building will be more cost-effective than improvements in the building envelope of the lab buildings.

EPA CAMPUS COMPONENT PEAK LOADS

LABORATORY
Total Load 64 MillionBtu/Hr



OFFICE
Total Load 18 Million Btu/Hr



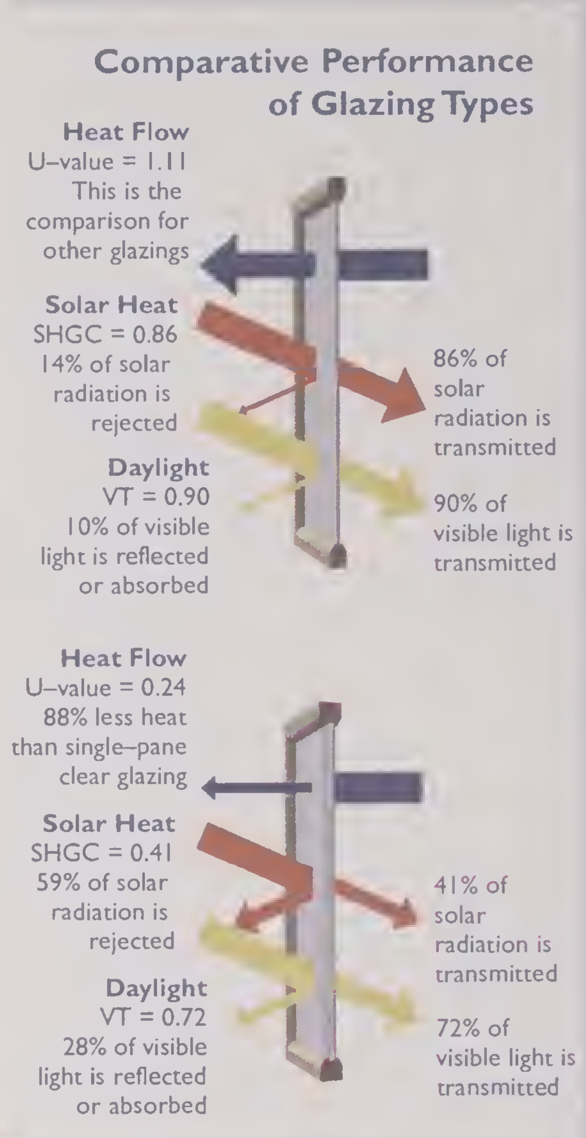
Sun Control

A key goal of sun control is to provide beneficial daylighting for building occupants while blocking unwanted glare and heat gain. The facility's facades incorporate some architectural sunshading through the deep profile of the precast concrete cladding. Clusters of tall trees, some as high as 80 feet, which were preserved during site design, also provide valuable shading for the west side of the low three-story office buildings. Low-E glazing and interior mini-blinds complete the sun control strategy in office areas.

Motorized shadecloth blinds are used in public areas in the central office tower. However, the lab buildings do not require interior blinds because all of the occupied spaces are inboard and the deep articulation of the precast concrete outer walls help shade strong midday sun. The cafeteria and training area facades, with 12-foot-high floor-to-ceiling glass overlooking the lake, incorporate a deep architectural trellis planted with deciduous vines that provide maximum sunshading in summer and partial sunshading in winter.

Glass Selection

The performance of types of glazing varies tremendously. Compared to most tinted and reflective glazings, spectrally selective Low-E coatings provide a higher level of daylight for a given amount of solar heat reduction. This feature is especially important in cooling-dominated climates. The Comparison of Glazing Performance (below) indicates that the improved Low-E double glazed insulating unit with spectrally selective glass has the highest Coolness Index (CI) of all. This ability to transmit light without heat is a major technological achievement. For the EPA facility, the improved Low-E is used on southern and western exposures and the atrium roof. Standard Low-E is a lower cost option and provides sufficient performance for the northern and eastern exposures.



Single pane clear glass (top) and double pane glass with spectrally selective low–E coating (bottom)

Comparison of Glazing Performance

Glazing types used at EPA

Glazing Type	U-Value (Winter/Summer)	Shading Coefficient	Visible Light Transmittance	Coolness Index (CI)
Single pane clear glazing	1.09/1.03	0.94	89%	.94
Double pane clear glazing	0.48/0.55	0.81	79%	.97
Bronze tint on clear double pane glazing	0.44/0.52	0.29	18%	.62
Low-E coating on clear double pane glazing	0.31/0.32	.59	73%	1.24
Low-E coating on green spectrally selective double pane glazing [1]	0.31/0.33	0.47	63%	1.34
Improved Low-E coating on green spectrally selective double pane glazing	0.29/0.30	0.35	60%	1.71
Heat Mirror™ 88 1" insulating unit with green glazing [2,3]	0.32/0.37	0.44	61%	1.38
Heat Mirror™ 44 1" insulating unit with green glazing [2,3]	0.31/0.35	0.24	32%	1.33
Super Windows	0.13	0.36	54%	1.5

[1] Spectrally selective glass has different performance depending on the color.
[2] Performance will vary depending on the film used, heavier films reduce light transmittance and lower shading coefficient, but U-value remains about the same, HM88 and HM 44 are shown to demonstrate some of the range.
[3] Assumes 1" insulating unit, 1 1/2" insulating unit will have a U-value of 0.23/0.27 for HM88 and 0.21/0.24 for HM44.

Building Envelope
Refers to a building's exterior skin. Particularly important is the extent to which it allows or resists the passage of air, light, heat, moisture, sound and pests into and out of the building.

Coolness Index (CI)
Sometimes referred to as efficacy (ke), this is the ratio of visible light transmittance to shading coefficient; a higher number indicates better admission of daylight with less accompanying heat gain.

Low-E
Low-emissivity, a term used by the glass industry for microscopically thin metal or metallic oxide layers deposited on a window or skylight glazing surface primarily to reduce the U-factor by suppressing radiative heat flow. A typical type of low-E coating is transparent to the solar spectrum (visible light and short-wave infrared radiation) and reflective of long-wave infrared radiation.

R-Value
A measurement of the resistance of a material to the transfer of heat. Insulation having high R-value is important for walls, roofing and foundations. Windows and doors may have improved R-values depending upon their design.

Shading Coefficient
measures the total solar heat gain through the glazing compared to 1/8" clear glass under the same design conditions; the lower the shading coefficient, the lower the solar heat gain.

Thermally Broken Windows

The largest disadvantage of aluminum as a window frame material is in its high thermal conductance. Unless "thermally broken," the frame readily conducts heat, greatly raising the overall U-factor of a window unit. Moisture accumulation in the building can also become a problem if it becomes cold enough outside to condense moisture or frost on the inside surfaces of window frames. Consequently, all aluminum window frames for the EPA Campus are fully thermally broken. This feature will not only improve comfort, but it will also eliminate condensation that could lead to the growth of molds and mildew, thus preserving good indoor air quality.

Light shelves at National Computer Center

Light Shelves

Metal light shelves that would also act as a sun screening element were explored during design. While light shelves can enhance the use of daylight in office areas, the potential benefits for the EPA offices were limited because of the high proportion of interior closed offices. In addition, deep window ledges and the tall existing trees adjacent to the building already provide some sunshading. Consequently, at a cost of approximately $500,000, light shelves were determined not to be the most cost-effective way to improve performance. Instead, improved low-E glazing was used on the west and south facades for a premium of $10,000. The result was almost as good as the $500,000 solution and was much more cost-effective.

Insulation

Due to North Carolina's mild climate and the relatively small contribution of the building envelope to overall thermal loads, super-insulation is not a cost-justifiable strategy in the new facility. Even in the winter, the office buildings will be in cooling mode most of the time, and the lab buildings will be minimally affected by their insulative value. Due to the internal loads generated by people, lights and computer equipment, offices on the interior are cooled virtually year round. In a typical office building, the envelope is 15-20 percent of the load, whereas the lights, equipment, people and outdoor air constitute the remainder of the load. In summer, light-colored roofing and cladding will contribute to heat gain reduction, putting less of a burden on the insulation to slow heat transmission. Therefore, insulation for the facility is provided in moderate quantities: U-values of 0.05 for the roof and 0.07 for the walls.

Infiltration

The infiltration of outdoor air can be a major source of heat transfer through a building's envelope. It can also introduce unwanted moisture into the building's interior. The EPA Campus used low-toxicity, high performance caulks and sealants to minimize unwanted heat loss and heat gain, to maintain required pressurization relationships between office and lab, and to prevent infiltration of exhaust air or ground contaminants. Air locks are provided at all public entries.

Albedo Control

Roof and exterior wall surfaces that reflect rather than absorb light limit heat absorption through the building envelope. The measure of light reflectivity is called "albedo." Generally, materials with high albedo are light in color. Consequently, the project team chose white single-ply roofing (albedo of 0.78) throughout the facility to limit heat gain, and reduce air conditioning requirements. With an "emissivity" of 0.90, this roofing will also shed it's absorbed heat relatively quickly. Even though studies show that similar white roofs lose up to 25 percent of their albedo within the first three years following installation due to dirt accumulation, the performance stabilizes at a level of about 0.60 albedo, which is still significantly better than typical black-roof surfaces.

The building cladding is a light beige precast concrete, with beige concrete masonry units at the building base and cores. These light-colored surfaces will also contribute to reduced cooling requirements for the facility.

Albedo and Emissivity of Materials

Material	Albedo	Emissivity
Concrete	0.3	0.94
Tar paper	0.05	0.93
Bright galvanized iron	0.35	0.13
Bright aluminum	0.85	0.04
Aluminum Paint	0.80	0.27 - 0.67
White single ply roofing	0.78	0.90
Black EPDM roofing	0.045	0.88
Gravel	0.72	0.28

Source: The Protocols of White Roofing by James I. Seeley, published in The Concrete Specifier, November 1997

Operable Windows

Air pressure relationships within the facility control the flow of air between the lab and the office portions of the building. These pressure relationships enhance safety within the building by ensuring that air in laboratory areas cannot migrate into office areas, which are under positive pressure. The pressure relationships also keep odors and fumes from spaces such as loading areas, trash docks and print rooms out

Thermal Break
To solve the heat conduction problem of aluminum frames, the frame is split into interior and exterior pieces and a less conductive material such as plastic is used to join them. Current technology with standard thermal breaks has improved aluminum frame U-factors from roughly 2.0 to about 1.0.

U-Value
A measure of heat flow is the inverse of R-value (R=1/U).

Albedo
A measure of the light reflectance of a material, whether a building material, paving, ground cover, etc. Building materials with high albedo (lighter colors) reflect more light off their surface and reduce the overall heat gain through the building's envelope.

Emissivity
The rate at which absorbed energy is radiated away from an object; a desirable roofing membrane will easily release its absorbed heat energy and keep the roof cooler.

of the airstream. Operable windows would compromise the EPA's facility's pressure balance, and could create indoor air quality problems due to the region's high humidity and heavy mold and pollen loads.

However, to help bring fresh air inside during good weather, an outside air economizer system has been integrated into the design. When outside temperatures permit, and humidity is not too high, the outside air economizer system provides cooling with up to 100% outside air, filtered to remove dust, pollen and mold spores.

Space Planning

Key Issues to Consider

- Develop flexible space plans using modular design that anticipates future needs
- Develop mechanical, electrical and plumbing infrastructure that anticipates future needs and can accommodate change
- Improve efficiency of the building through the use of shared spaces

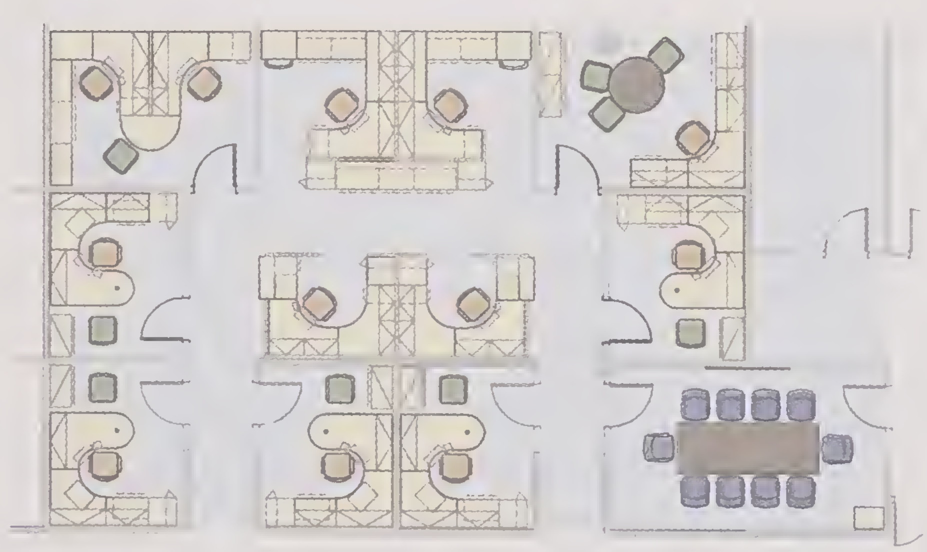
Space planning has a significant impact on the overall environmental performance of most facilities. Depending on how the space is designed, it will either become obsolete after a short period of time and require complete renovation, or it will be flexible enough to meet future needs with a minimum of effort. Consequently, increased flexibility enhances building longevity, thereby conserving material resources and reducing waste streams.

The new facility has been developed with a flexible organizational system to accommodate movement of personnel, changes in research programs and changes in the mix of labs and offices.

Modular Office Design

To minimize the demand for office alterations, the design accommodates a limited number of office sizes. Two basic sizes are provided for closed offices, and two sizes for open workstations. The fundamental building block for office planning is a 36-by-50-foot "pod" with fixed demising walls that separate one pod, or suite, from the next. While this pod can accommodate open and closed offices in several different ways, a 20-foot-wide zone along the windows is always dedicated for open workstations so that people in the interior zone of the office floors will have access to natural light.

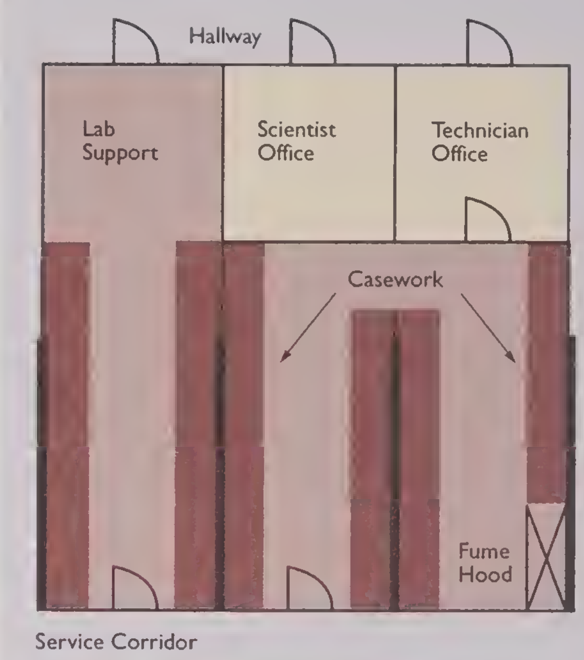
When reconfiguration is necessary, the perimeter suite walls, lights, sprinklers, ceiling grid and electronic sensors can usually remain in place. Construction is mostly limited to those partition walls within the pod that must be changed to accommodate a different proportion of closed to open, or large to small offices. Demountable partitions were considered but not chosen because the need for reconfiguration within the office areas will not be frequent enough to justify the additional investment.



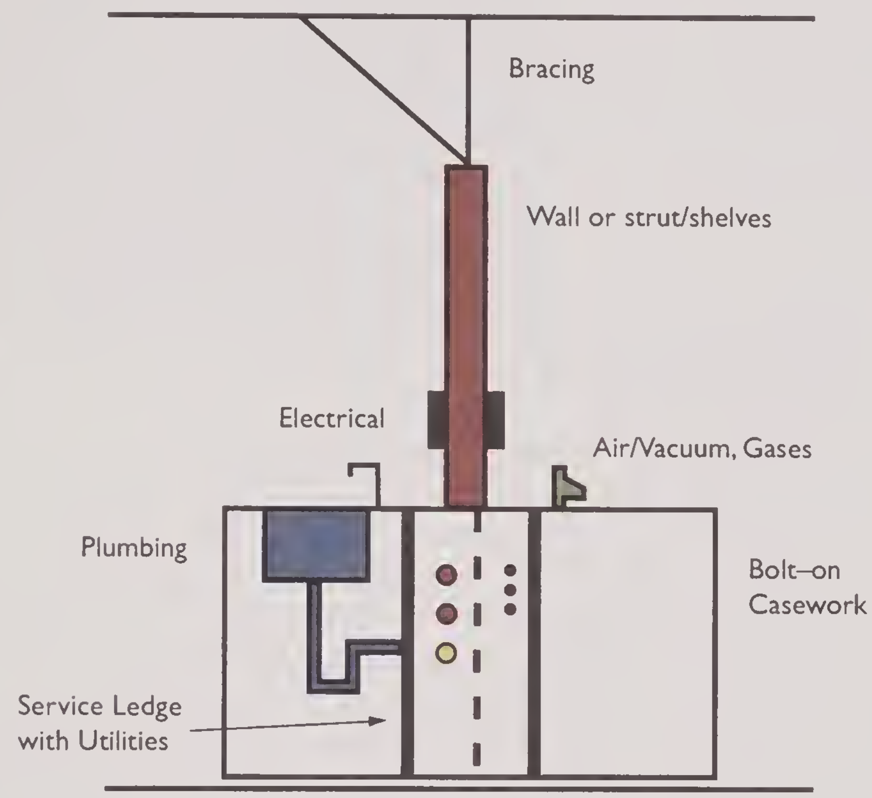
Standard office suite configuration

Modular Lab Design

The laboratory space is designed to provide safe and efficient layouts with easy access to utility services and investigator offices. A service corridor provides access to essential plumbing, exhaust risers, electrical panels and bottled gases. The telecommunications backbone bisects each floor plate. Modular lab "building blocks" measuring 11 feet by 23 feet are arrayed to each side of the service corridor, and an adjacent 11-foot by 12-foot support/office block provides added flexibility to house science or scientists. A service ledge containing all lab support utilities provides the core element for multi-module peninsula benches or the base structure for utility free dividing walls. Modules can be easily combined by leaving out these wall segments (up to eight modules in width), or by extending the base module to 33 feet by using the lab support module. Conversely, adding a wall atop a peninsula bench allows easy division of larger labs into smaller labs without disrupting electrical or piped utilities.



Typical Laboratory Plan



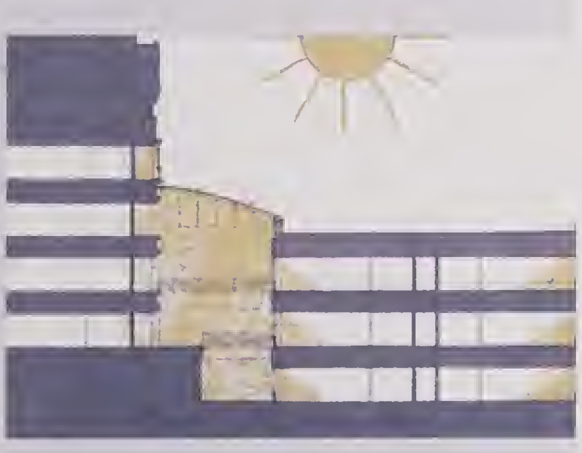
Utility distribution to lab benches is provided through the fixed service ledge which supports and protects all utility piping. Services include gas, compressed air, vacuum, water and electricity for various kinds of specialty equipment and instrumentation. Since utility lines do not normally need to be moved when labs are reconfigured, there is less disruption, costs are minimized and demolition waste is drastically reduced.

Lab casework and counter tops are designed in three- or four-foot units, each with pullout writing boards and either high or low bench heights. Kneehole spaces feature lockable computer keyboard drawers, and wall cabinets and open-wire shelf units are fully adjustable. This allows ready reuse of laboratory casework over the years of occupancy. The EPA labs have been developed so that all changes, except those that affect the size of the lab, can be made without construction. When construction is required it is limited to gypsum partitions between labs, while the floor, ceiling, lighting, sprinklers, diffusers and lab services all remain intact.

These conserving strategies greatly extend the service life of labs and equipment, and reduce the quantity of lab furnishings and building materials typically hauled to landfills. Waste from future renovations is limited to gypsum wall board and steel framing, both of which are fully recyclable. Finally, very little research time will be lost waiting for renovations to be completed.

Key Issues to Consider

- Minimize the building's exterior perimeter by connecting otherwise separate buildings
- Draw natural light into the building interior, but avoid over-lighting
- Minimize heat gain and heat loss through the atrium roof/ skylight



Section through the central atrium

Building Atrium

Building atria can enhance the functionality of a building by providing large enclosed spaces that contribute to the sense of community within a facility. The atrium for the new EPA facility was seen as an important strategy to encourage interaction between EPA employees, not just within work groups but across disciplines. When properly designed, atria can also serve as energy conservation features that reduce heat gain and loss while bringing natural light into a building. However, careful skylight design is necessary if the potential energy benefit is going to be realized. If designed without proper care, an atrium can trap solar heat in the summer and lose heat through the skylight in the winter, greatly increasing energy usage.

Building Massing

The building massing of the EPA Campus has been developed to reduce exterior surface area while addressing the desire for a predominantly low-rise facility. A series of building atria connect laboratory and office buildings, to bring daylight into the facility while providing a main street of circulation for the complex of buildings. From a design perspective, the atria connect two otherwise separate buildings, reducing the exterior perimeter by exchanging skylight area for what would otherwise be exterior vertical walls. The connection provides savings, both in capital costs and energy costs.

Energy and Daylighting Analysis

The goal for atrium skylighting is to meet required functional and aesthetic requirements while balancing daylighting and energy goals. To optimize the design of the atrium skylight, the project team used energy and daylighting analysis to assess heat gain and loss through the atrium skylight, illumination requirements that could be met with daylighting, and heat gain associated with electric lighting.

The original atrium design called for a top-of-the-line, all-glass skylight, with high-performance low-E glazing. However, the project team quickly realized that this approach was problematic. The atrium skylight would have provided too much light. The light converts to heat energy inside the building, which impacts the overall building cooling load. Excessive lighting also causes visual discomfort from harsh levels of contrast. However, simply lowering the visible light transmittance of the glass would have resulted in a gloomy, gray sky appearance, with high levels of interior reflectance on the glass.

After adjusting model parameters for six different atrium roof options, the optimum skylight design was selected. Using the same high performance glass for approximately 26 percent of the surface, the remainder of the atrium surface was comprised of translucent panels with improved insulative value, and opaque panels filled with insulation. The revised design reduces the atrium's peak energy usage by two-thirds compared to the all-glass skylight. The solution still provides plenty of light, so that the perimeter of offices facing the atrium will require very little artificial lighting.

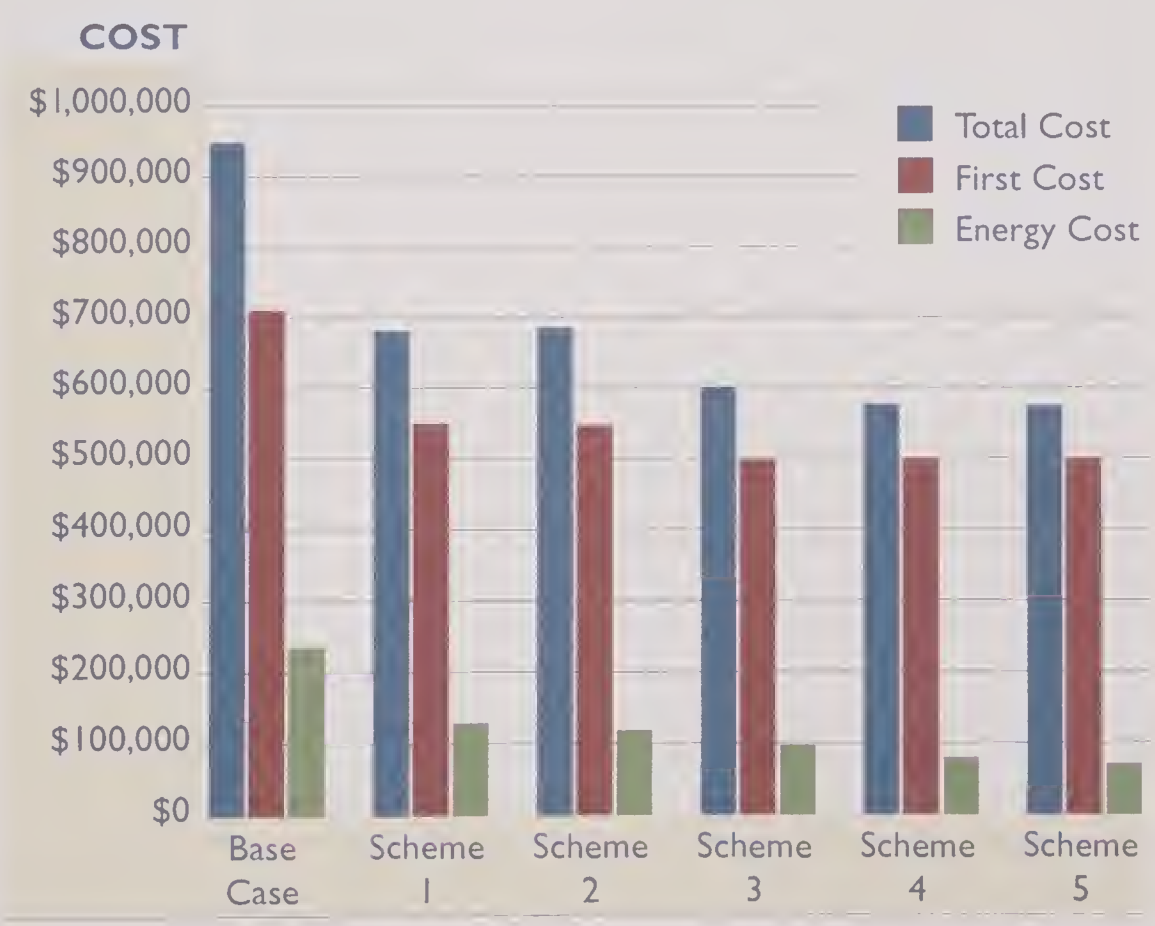
It is difficult to calculate the net benefit of the new facility's atrium without a detailed energy analysis of a similar scheme with no atrium. For comparison purposes, the office portions of the adjacent central office tower next to the entry plaza were determined to operate on the same schedules and at the same density as the office buildings connected by the atrium. Energy calculations indicate the office buildings fronting the atrium use 37,400 Btu/SF/Yr versus 41,000 Btu/SF/Yr for the freestanding tower, a 10% reduction in energy consumption. This reduction is primarily related to decreased exterior surface.

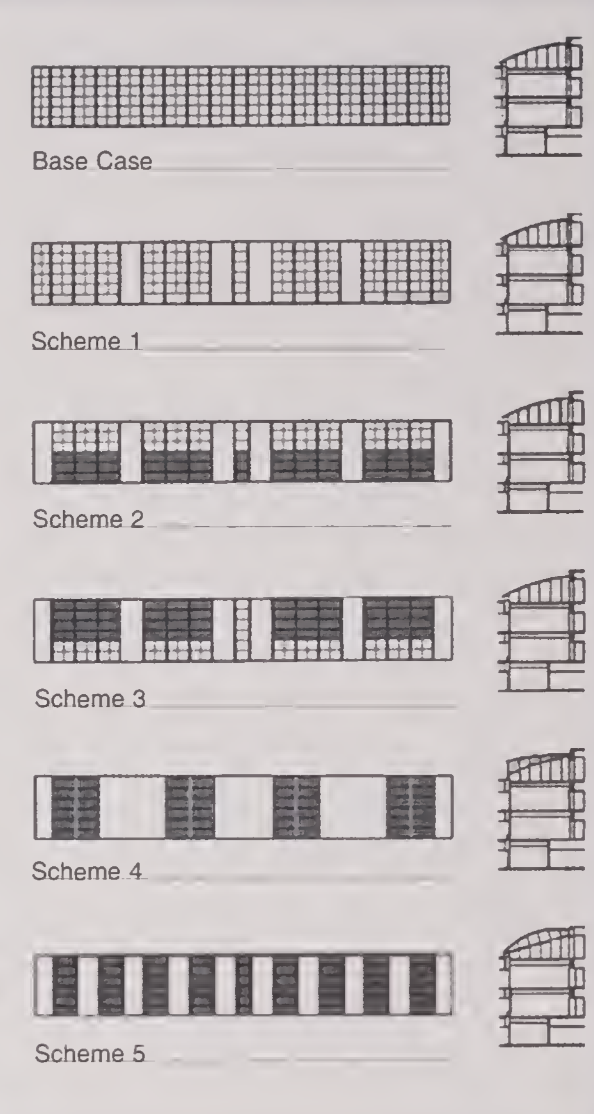
Central atrium

Atrium Skylight Options

Multiple skylight options for the EPA project were considered (see diagram). A comparison of the first cost and the energy cost over a 20-year life cycle was provided for each. Schemes one and two were eliminated due to their relatively high cost and comparatively low energy performance. Schemes three, four and five had remarkably similar cost and energy performance.

Scheme three is a modified version of the original skylight that faces west. In contrast, schemes four and five introduce a series of clerestory windows that face north and south, a traditionally-preferred approach for passive solar design that eliminates the western exposure. The energy analysis showed a surprisingly small added energy benefit for schemes four and five. Scheme three was ultimately chosen because it would be easier to maintain, due to its single, continuous slope as opposed to multiple peaks and valleys. Scheme three also allowed a clear view of the sky from the interior.





Atrium skylight options

Key Issues to Consider

- Maximize the benefits of natural daylight
- Select high-efficiency, long-lasting light sources and high-efficiency fixtures
- Make use of task lighting
- Balance lighting efficiency with visual comfort
- Control the balance between natural and artificial lighting with sensors and dimmers where appropriate

Ambient Light
The overall lighting level of a space, including primarily daylight and overhead lighting.

Ballast
A device used to operate fluorescent and HID lamps. It provides the necessary starting voltage, while limiting and regulating the lamp current during operation.

Color Rendering Index (CRI)
A scale of the effect of a light source on the color appearance of an object compared to its color appearance under a reference light source (low numbers indicate unnatural appearance; 100 indicates no color shift).

Compact Fluorescent Lamps (CFLs)
Fluorescent lamps that are configured to fit into a standard incandescent socket. Many models contain an integral ballast.

Dimming Systems
Controls that automatically turn down the artificial lighting in areas that receive sunlight during the daylight hours to save electricity and reduce the building's cooling load.

The outcome of this rigorous analysis was the selection of an atrium skylight design with reduced construction cost, combined with excellent daylighting and thermal performance. In addition to the energy and cost benefits, the atrium design contributes to the aesthetic quality, with a forest-like mix of brightness and shade, intermingled with views of the sky.

Lighting Systems

When electricity use and the increased cooling load due to electrical lighting are considered together, electric lighting generally represents approximately 15 percent of the overall energy consumption in typical office buildings. Efficient lighting requires appropriate use of daylight, an accurate assessment of required lighting quantities, use of efficient lamps, ballasts and fixtures, and measures to reduce unnecessary lighting during unoccupied hours. For the EPA Campus, the combination of sensor controls and high-efficiency fixtures produced lighting that is approximately 70% more efficient than a standard code-compliant building.

Besides the energy issues associated with electric lighting, there are quality of life and productivity issues to consider. Excessive illumination can create visual discomfort, glare, headaches and fatigue while increasing energy consumption and associated pollutant emissions. Greater use of daylighting, reduced glare, good color rendition, elimination of lamp flicker and correct lighting levels can contribute to the productivity and well being of a building's occupants.

Green Lights

EPA's voluntary Green Lights program encourages companies to upgrade their lighting. While the efficient lighting technologies have a higher first cost, their payback periods are quick. Participants in the Green Lights program have found that, on average, their lighting improvements have generated a 30 percent rate of return. Although originally intended for existing buildings, the Green Light principles are equally valid for new construction. Consequently, the project team for the EPA Campus implemented the full range of measures described in the Green Lights program, including high-efficiency lamps and ballasts, task lighting, photoelectric dimming controls, occupancy sensors, a central lighting control system and bulb maintenance. The combination of sensor controls and high-efficiency fixtures produced lighting for the new Campus that is about 70% more efficient than standard code-compliant buildings.

Daylighting

The EPA Campus design promotes the use of daylighting in a number of ways. The building atria that connect lab and office buildings bring daylight into the building interior. All exterior glazing has high visible light transmittance and a low shading coefficient to provide "cool light." Interior space planning supports daylighting through the use of light color finishes, low partition heights and a planning concept that designates almost 50 percent of the perimeter space planning zone to be dedicated to open office workstations. This zone keeps exterior windows unobstructed so that light can penetrate interior office zones.

Task Lighting

Task lighting directs light onto a work surface or object that requires illumination. This allows the general or "ambient" lighting levels to be reduced to a more comfortable level. Ambient lighting levels for the EPA Campus were reduced in anticipation of task lighting which will be used in all office and lab areas. The office areas are designed to 30-40 Foot Candles (FC) ambient and 50 FC task, and the labs are designed to 70-80 FC ambient and 100 FC task.

Laboratory Lighting

The laboratories for the EPA Campus are lit with direct and indirect lighting that is complemented by task lighting on the work surface. Numerous options were evaluated. The direct/indirect lighting scheme proved to be considerably more efficient than a traditional scheme using down lighting alone. It also provides better quality lighting. The indirect component enhances the spread of light while the direct component improves overall efficiency as well as depth perception.

The direct/indirect scheme also reduces the connected watts per square foot (SF) from 1.85 to 1.38 when compared to the direct lighting scheme alone. This is because only one row of three-lamp fixtures is required instead of two rows of two-lamp fixtures. This scheme also generates first cost savings. Light distribution studies developed for the selected indirect/direct scheme demonstrate that the spread of light in the labs will provide the desired quality.

Computer-generated radiosity study of typical laboratory

Office Lighting

In the office areas, indirect lighting proved to be less efficient and more expensive than direct lighting. This was due to the high proportion of closed offices required in these areas. Consequently, office areas for the EPA Campus are lit with two-foot by four-foot recessed fluorescent downlights with compact fluorescent downlights in the circulation zones. Even so, this scheme requires less than one connected watt per SF. Daylight dimming and occupancy sensors in the office areas further reduce lighting requirements, so that the anticipated energy use for lighting is only about 0.6 watts per SF.

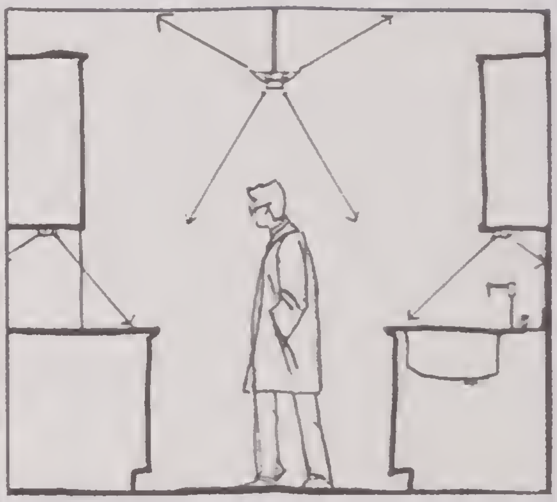
Special Spaces

The lobby, cafeteria, conference center and breakout spaces in the atria are areas that traditionally would receive some incandescent lighting. However, with the advent of improved fluorescent lamps with high color rendering indexes (CRI) and no flicker, this preference is no longer valid. The EPA Campus uses compact fluorescent fixtures supplemented with metal halide fixtures in public areas where a stronger, more intense source is desired.

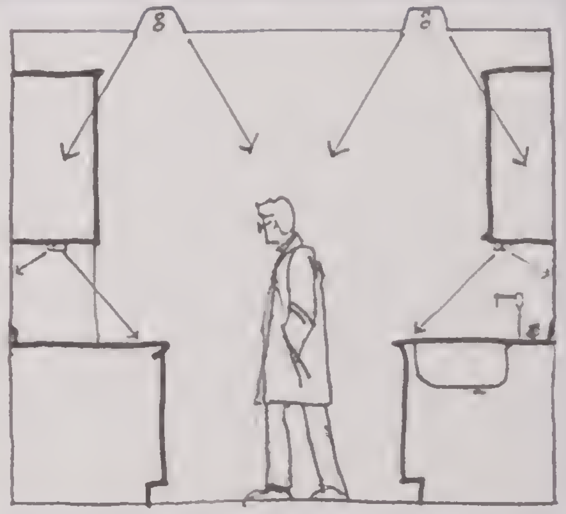
Direct lighting
Illuminates a surface or space directly from the light source, whereas indirect lighting reflects the light off other surfaces.

Downlight
A type of ceiling luminaire, usually fully recessed, where most of the light is directed downward.

Fluorescent
A lamp that produces visible light by emitting electromagnetic radiation and is much more efficient than incandescent, requiring only 15-30% of the energy to produce an equivalent amount of light.



Typical laboratory section with direct / indirect lighting supplemented by task lighting



Typical laboratory section with direct lighting supplemented by task lighting

Occupancy Sensor
A control device that turns lights off after the space has become unoccupied.

Photocell
A light sensing device used to control luminaires and dimmers in response to detected light levels, saving electricity when daylight is sufficient.

Task Lighting
Any form of light that is focused on a specific surface or object. It is intended to provide high-quality, flexible, lighting for a predetermined activity.

Exit Signs
- There are more than 100 million exit signs in buildings throughout the United States, operating 24 hours a day, 365 days a year
- Cumulatively, we spend about $1 billion per year just to operate all the exit signs in buildings in the U.S.
- Beginning in the year 2000, companies could save 800 million kilowatts of electricity per year through the use of EPA Energy Star compliant exit signs, a total of almost $70 million each year
- A typical long-life incandescent exit sign consumes 40 watts and must have the lamps replaced every eight months
- A typical compact fluorescent exit sign consumes 10 watts and must have the lamps replaced every 1.7 years
- A typical Light Emitting Diode (LED) exit sign consumes less than 5 watts and has a life expectancy of more than 80 years. (An LED is a solid state light source with no filament)

Source: Energy Efficient Lighting Association, 1998

Central atrium

Lighting Controls

Many types of automated control systems have been developed to reduce the use of electric lighting when it is not needed. These systems include a variety of photoelectric sensors for dimming in response to daylight, occupancy sensors that shut lights off when occupants leave the room, and time clock controls that shut lights off based on occupancy schedules. Lumen maintenance controls use dimming to undo the overlighting that is typically employed to compensate for degradation of lamp output over time.

The EPA Campus uses several of these systems in its lighting strategy. Photoelectric sensors for daylight dimming control are used in the building atria, the cafeteria and conferencing center, and in office building perimeter zones, including office areas that face the atria. Photoelectric sensors are also used to control lighting in the parking garages. Occupancy sensors are used to control lighting in open and closed office areas, as well as support areas such as storage rooms, copy rooms and small conference rooms. However, occupancy sensors will not be used in labs for safety reasons. The Building Automated Control System also has a timeclock feature that will switch off lights inadvertently left on during off hours.

Exit Signs

Although exit signs are a seemingly minor concern, they are plentiful in buildings and are illuminated 24 hours a day, seven days a week. When relamping is considered, the differences between available options are magnified. For example, a typical long-life incandescent lamp in an exit sign must be replaced every eight months versus 1.7 years for a compact fluorescent, and 80 years for a Light Emitting Diode (LED) exit sign. To take advantage of the installation, operations and maintenance dividends, the EPA Campus uses LED exit signs throughout.

Building Mechanical Systems

Building mechanical systems that provide heating, cooling and ventilation generally account for as much as 50 percent of a typical building's total energy consumption. The efficiency of systems, however, varies considerably–as does the potential environmental impact. This impact can include resource depletion and habitat

destruction from the extraction of fuel, air emissions from combustion that create pollution and contribute to global warming, and ozone depletion from the release of chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerants in cooling equipment.

From both a cost and a pollution prevention perspective, investments in energy-efficient systems should be considered after all efforts have been made to eliminate unnecessary thermal loads. Energy conservation and energy efficiency strategies for the EPA Campus netted more than a 40 percent reduction in energy consumption for the overall facility, compared to average building energy performance statistics developed by the U.S. Department of Energy.

Energy Modeling

Energy modeling is an effective tool that allowed the project team to evaluate options and find cost-effective solutions. An energy budget was developed for the EPA Campus, providing modeling information on peak loading and operational energy use. While reductions in peak loading can lead to first-cost savings as systems are downsized, operational energy use must also be evaluated as an indicator of ultimate energy consumption. Producing an energy budget during the detailed design phase allows for an accurate simulation because systems have already been selected. However, it limits the ability of designers to make use of energy studies to inform system selection and architectural scheme design. Ideally, a preliminary energy budget should be developed in schematic design and used as a design tool, then updated during design development and final design phases.

Central Utility Plant

The EPA Campus shares a central utility plant with the National Institute of Environmental Health Sciences (NIEHS) facility across the lake. A separate utility plant for the EPA facility was originally considered because the elimination of the 36" chilled water (CW) and 14" high temperature hot water (HTHW) campus loop would have considerable first- cost savings and limit thermal transport losses. However, the use of a central plant has the advantage of scale that favors the use of high-efficiency equipment, shared operations, staff and equipment, redundancy and load balancing. The shared plant was ultimately endorsed and, in the current design, cross-connected underground pipes supply HTHW and CW to both the EPA facility and NIEHS.

In addition to shared equipment redundancy with NIEHS that offset some of the first-cost premium, the EPA Campus gained operational benefits associated with shared plant personnel. This shared redundancy proved to be a major cost and environmental savings to both EPA and NIEHS. One 3,500-ton chiller and one 40-million Btu/hour boiler were cut from the project, which eliminated the purchase, production and transport of enormous pieces of equipment. With less room needed for equipment, the central plant building expansion was reduced by 5,000 square feet.

High Efficiency Chillers and Boilers

The efficiency of chillers and boilers can vary considerably. However, even with high-efficiency equipment, chiller and boiler efficiencies are not fixed. Efficiencies can vary according to loading with some machines reaching peak efficiency at full load and others at partial load. Consequently, a good understanding of anticipated actual loadings, not just peak loading, is important for design so that the full load and the partial-load efficiencies of equipment can be evaluated and optimized relative to demand.

Key Issues to Consider

- Consider the primary fuel or energy source to be used
- Look for equipment that does not use CFCs or HCFCs
- Choose high-efficiency heating and cooling equipment, pumps and motors
- Minimize reheating of conditioned air
- Use variable frequency drives for fans and pumps, and variable air volume boxes for air handling
- Explore heat reclamation.
- Optimize distribution of mechanical equipment to minimize transport losses
- Consider setting goals that exceed federal benchmarks for efficiency

Heat Recovery System
Any system that recovers waste heat generated by building operation to satisfy part of the building's energy needs. Sources of heat include exhaust air, machines, lights, process energy and people.

Variable Air Volume (VAV)
A feature in a mechanical space heating/cooling system that uses an automatic control to adjust the air volume flow rate rather than adjusting the air temperature.

Variable Speed Drive
A device used to control the speed of an alternating current-driven motor by electronically varying the input voltage and motor frequency.

The chillers and the boilers specified for the NIEHS/EPA Central Utility Plant (CUP) are highly efficient units designed to operate at multiple settings. This allows their output efficiency to be optimized. For example, the CUP chillers consume 0.54 KW/ton at 50 to 75% loads. At 100% load, consumption increases to 0.63 KW/ton, and at only 25% load, the energy consumption is an even higher 0.77 KW/ton. In other words, extremely high or low loads are the least efficient operating modes. Because the design is based on multiple chillers in operation with a redundant chiller provided, 100 percent output will never be required and 25 percent loading will be minimized.

Variable Air Volume

Variable air volume (VAV) systems control temperature by varying the quantity of supply air based on the actual cooling required. VAV boxes can be set so that minimum outdoor air requirements are met while varying the supply air to suit the heating or cooling load in the space. In this situation, a variable speed drive on the air handler will slow down the fan, maintaining minimum system pressure and saving fan energy. In addition, the lower airflow passing across the cooling coil reduces the required heat transfer in the coil as well as the amount of chilled water used.

The EPA facility uses a non-powered VAV system in the office buildings and a dual-setting constant volume system in the laboratories. The straight system was used instead of a fan-powered VAV even though a fan-powered VAV can contribute to better air movement and air mixing within the office space. The straight system was selected because the fan-powered VAV is a high maintenance piece of equipment that consumes fan energy. The simpler "straight" system is a low energy alternative, and it also allowed EPA to specify an increased minimum airflow. The EPA facility provides a minimum of 2.25 air changes per hour (ACH) of outdoor air, which exceeds the one ACH minimum recommended by the American Society of Heating and Refrigeration Engineers (ASHRAE) 62-89.

Outside Air Economizer Cycle

Each of the air handling units for the offices and the labs at the EPA Campus is equipped with an outside air economizer cycle with enthalpy controllers to sense relative humidity and protect the building from overly humid air. Outside air economizer cycle operation (also known as "free cooling") allows the air handling unit to operate at up to a 100 percent outdoor air mode when the outdoor temperature and humidity allows. It is the mechanical equivalent of the open window.

Economizers become active when outdoor air temperature is at or below 55 degrees. If the outdoor temperature continues to drop below the supply air temperature (55 degrees), the system mixes outdoor air and return air to maintain temperature. Economizer cycles create tremendous savings in climates that are mild much of the year and where humidity is not too high. Outdoor air economizers need to be addressed in the early stages of design because space for larger ductwork and shaftways is required.

Variable Frequency Drives

A variable frequency drive is a solid-state device hooked to the starter of a motor, fan or pump to allow for the motor speed to be varied according to the demand. This allows the system to take advantage of the slower speeds and to reduce energy consumption.

The EPA Campus uses variable speed drives on all water pumps and air handling units. Sensors in the piping system and the duct system monitor fluctuations in the static pressure or the water pressure, transmitting a signal to the variable speed drives to slow down or increase the speed of the motor depending on the conditions.

High Efficiency Motors and Fans

The heart of the HVAC system is the fan that pushes the air; the fan is required whether the process requires cooling, heating, ventilation or exhaust. Consequently, the specification of the highest efficiency fans and motors for use in the HVAC is an important step toward the development of efficient systems. The EPA specifications call for 90-95 percent efficient motors, a 10-15 percent savings over the customary 80-85 percent efficient motors. The specifications also call for high efficiency centrifugal and axial fans with variable frequency drives. By combining the highest efficiency fan design with variable speed demand high efficiency motors, a 15-20 percent overall savings in fan energy can be realized.

Heat Reclamation for Hot Water Generation

In the EPA facility, the high temperature hot water that has been circulated through heat exchangers to generate steam for the main building maintains sufficient heat to make domestic hot water. Consequently, circulating the water through an additional heat exchanger to make domestic hot water is an efficient use of the "surplus" heat. By maximizing the overall change in temperature, heat losses are reduced in site utility piping. This means that more of the energy per gallon of water is used and not wasted as system losses from site distribution.

Laboratory Fume Hoods

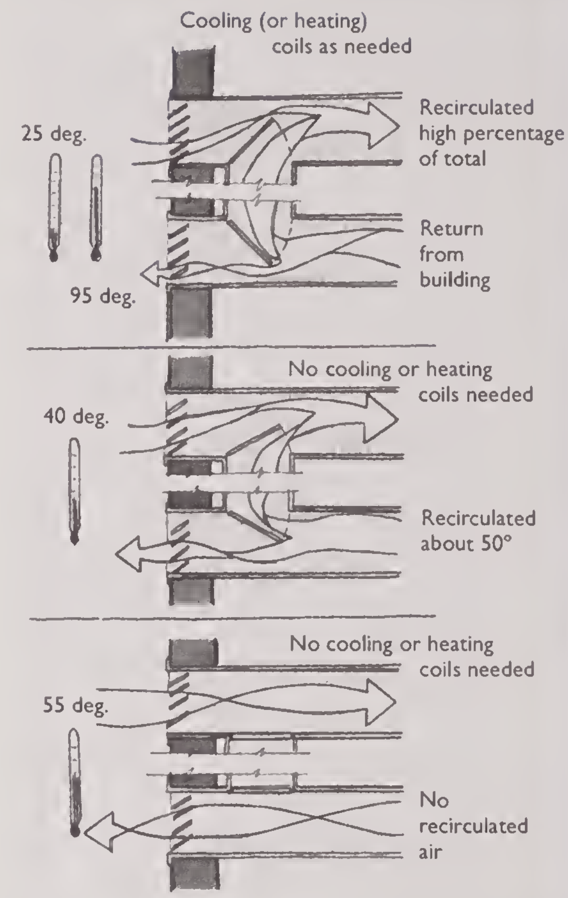
Laboratory fume hoods are vented enclosures provided for the safe handling of hazardous substances. They prevent the escape of contaminants to laboratory air, thereby providing containment. In addition, they typically provide most or all of the exhaust for the entire laboratory.

During the design of the laboratories, it was determined that there were limited options for conserving energy conservation in the fume hood systems while still meeting current EPA safety performance standards. The air change requirement in the standard chemical lab is 12 air changes per hour (ACH); other specialty labs can require up to 15 ACH. The design parameters at the outset of design were for a 1,400 cubic feet per minute (CFM) conventional fume hood, with no provision for nighttime setback. This EPA standard was based on the need for a minimum face velocity of 100 feet per minute (fpm) with the sash fully open.

The EPA's new standard hoods were modified to provide for an 80 percent sash stop on all of the hoods. The sash height reduction to 80 percent provides energy savings of 20 percent without compromising safety. This requires the researcher to manually override the sash stop for setups within the hood, placing the hood in "alarm" mode, and then to lower the sash back to the 80 percent stop or lower while chemicals are handled within the hood. The sash height reduction requires that operators understand the system and not attempt to work with the hood 100 percent open.

The design of the laboratories evolved to accommodate two-position variable air volume control for each lab module. Called a "nighttime setback," this feature allows for energy savings in the lab module during unoccupied hours. A two-position supply volume box is provided in each lab module. Each fume hood is connected to a riser with a two-position exhaust volume box in the penthouse. The system has been devised so that when the fume hood is at maximum flow, the volume boxes are positioned to provide for a flow of 1120 CFM through the fume hood. If the lights are off and the sash is closed on the fume hood, the volume boxes will reduce the airflow through the lab module by approximately 50 percent. This saves energy by reducing the air handling unit flow rate and slowing down the motor on the fans. The reduced airflow eases cooling and reheat requirements. Fan energy is also saved when the exhaust requirements are reduced by using variable frequency drives on the exhaust fans.

Economizer Cycle
(aka "outside air economizer") A system whereby cool outdoor air is used, as available, to ease the burden on a refrigeration cycle as it cools recirculated indoor air.



Economizer cycle controls the relationships between supply and return air:

- When outside air is hot (or very cold) the economizer cycle is inactive
- As very cold outside air gets warmer, it can be blended with recirculated air, and neither heating nor cooling coils are needed
- When outside air is cool, it can completely replace recirculated air, making mechanical cooling inactive

Source: Stein and Reynolds, Mechanical and Electrical Equipment for Buildings, 1992

Conventional Fume Hood
One of the oldest forms of laboratory fume hood, it is designed so that all exhaust air is drawn in through the front face opening. This type of hood can suffer from excessive face velocities and poor containment because the air velocity at the face increases proportionately as the sash is lowered.

Fume Hood Energy Conservation Strategies

Sash Height Reduction
Because fume hood exhaust air quantities are determined by the area of the face opening and the need to maintain a minimum face velocity, a reduction in the sash height reduces the total required air flow.

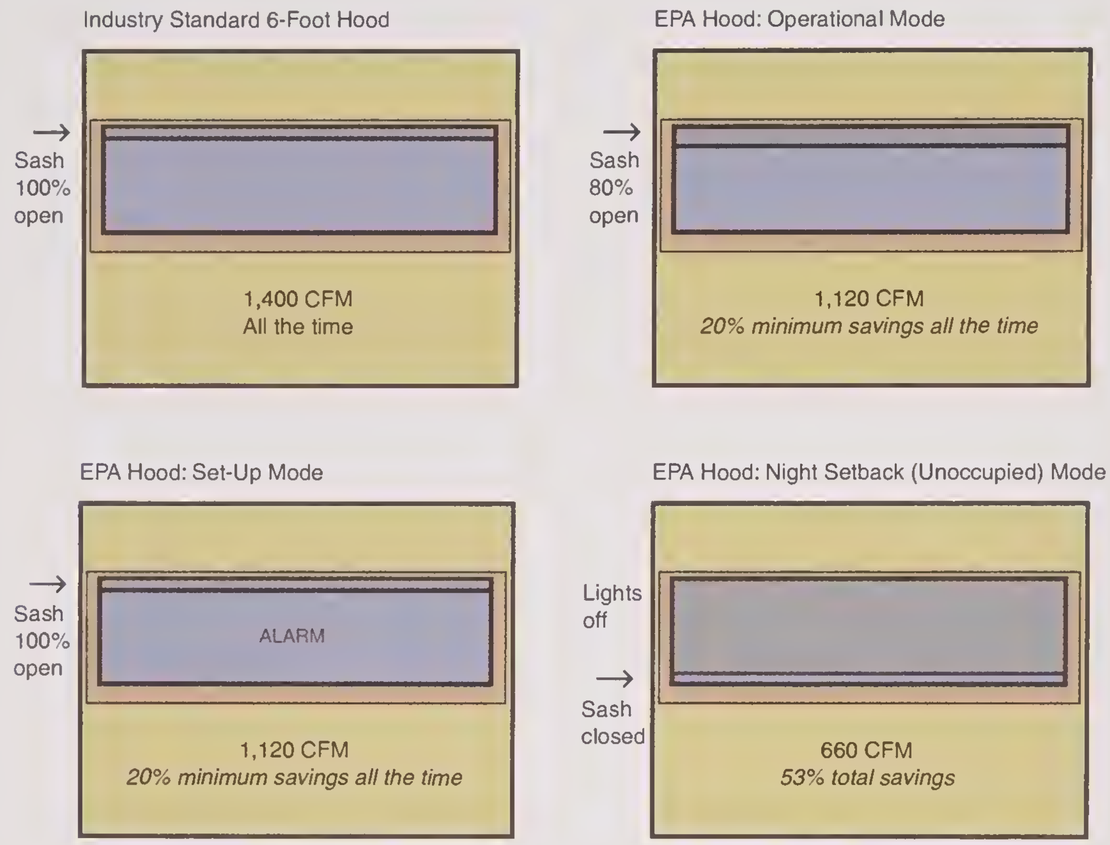
Night Set Back
A sliding sash closes the fume hood and slows air flow during evening or unoccupied hours.

Variable Air Volume Fume Hood
Provides a constant velocity across the hood face opening by varying the supply and exhaust air volume when the sash is opened or closed. Requires sophisticated controls and a response time of not more than five seconds to safeguard against backdrafts.

Horizontally Sliding Sash
Horizontal panels reduce the face opening decreasing the total required air flow.

Combination Sash Fume Hood
Horizontal sashes are used in combination with vertical sashes, providing the opportunity to save air flow by restricting the sash opening either vertically or horizontally.

Other energy conserving options, such as full VAV and combination vertical/horizontal sash fume hoods, were considered and rejected by the EPA team. EPA placed a high priority on low maintenance solutions that do not require expensive operator training. Some of the newer energy conserving strategies had too few successful installations to validate them when the design decisions were being made for the EPA Campus.



Heat Recovery for Laboratory Exhaust

Heat exchangers operate in a number of different ways depending on the medium that is being used, and the proximity of the intake and exhaust streams. Their function is to use waste heat and waste cooling to accomplish preheating and precooling. The potential for energy savings can be quite high, particularly for building types like laboratories that require large volumes of conditioned air to be exhausted.

A value engineering study prepared during concept design for the EPA facility evaluated the cost-effectiveness of installing a glycol runaround system in the laboratory air handling equipment. The glycol system was proposed because it avoids possible contamination between air streams, and won't freeze in the outside air stream. In the winter, warm exhaust air transfers heat to a glycol solution, which is then pumped to the coil in the air handling unit to preheat outdoor air. Incoming air is warmed as it passes over the glycol loop before passing through the heating coil, thus reducing the energy required to heat the outdoor air. This is also true in the cooling season where cooler exhaust air cools the glycol solution, which then precools the outdoor air.

Much to everyone's surprise, the study indicated that the glycol heat recovery system would cost $915,000 to install and approximately $8,900 more per year to run than the system without the runaround cycle. This cost differential was attributed to the extremely low electric rates of the local electric power provider and the absence of profound, long-duration extremes in North Carolina weather. The glycol system had increased fan static pressure caused by the heat recovery coils, and additional energy

requirements for the glycol loop pumps. The energy to run the reheat system was enough of an additional load to actually make heat recovery a more expensive system to operate. As a result, EPA did not install a heat recovery system, but provided space in the mechanical penthouse to allow installation of a system should technology and economics make heat recovery a prudent choice in the future.

CFC Free Refrigeration Equipment

Because of the impact CFCs have on the ozone layer, CFC refrigerants have been largely replaced by HCFC substitutes. Federal legislation has mandated strict phaseout dates that further impact decision making. Among the common substitutes for CFCs are HCFC-22, which has one-twentieth the ozone depleting potential of CFC-11 and will be phased out in 2020; HCFC-123 which has less than half the ozone depleting potential of HCFC-22 and will not be phased out until 2030; and HFC 134a, which has no measured ozone depleting potential and does not have a phase out date scheduled at this time. There are pros and cons to HCFC-123 and HFC-134a, the two most viable substitute refrigerants. While HCFC-123 is more efficient, it is scheduled to be phased out of production due to its ozone depletion potential. HFC 134a is a safer alternative that has less ozone depleting potential, but is a higher pressure refrigerant that is slightly less efficient and requires slightly larger equipment and more floor area.

In the end, EPA selected HFC-134a because it is a 0-rated refrigerant for ozone depleting potential. Gas absorption chillers were rejected as an option because the cost was prohibitive given the extremely low electricity rates at RTP.

Building Humidification

Humidification is recommended in regions where winter conditions are particularly dry and may adversely impact the health and well-being of occupants in office environments. In laboratories, humidification can be essential to the success of research projects. To provide the necessary humidification, the EPA facility uses a water atomizing system that employs compressed air and softened water to provide a minimum relative humidity (RH) of 35 percent in the laboratories and offices. A value engineering study verified that energy savings made this type of system cost effective even with its higher first cost. Steam systems require high temperature hot water to be converted to steam with special re-boiler generators that have inherent inefficiencies, as well as heat loss from piping. With the water atomizing system, cooling requirements are reduced because cool vapor from the humidifier acts as an evaporative cooling medium, giving the system a certain amount of free cooling in the air stream. Because of these savings, the cost of the system was acceptable.

Central Direct Digital Control (DDC) System

Central control systems allow building operators to have close control of their equipment and save energy by allowing systems to be turned down or off when they are not needed. The typical direct digital control (DDC) system uses a central computer and remote control panels into which the various pieces of equipment are wired for control. The system has an electronic base and is far more accurate than the pneumatic (compressed air control) systems of the past. Even if the main computer console goes down, the remote panels can stand alone and continue to control the equipment.

A central DDC system has been specified to control all of the HVAC systems and many of the electrical components as well. The building operator will be able to monitor multiple control parameters including temperatures, pressures, whether lights and fans are on or off, whether filters are clogged and other aspects of air handling units as well as pumps and cooling tower operation.

Global Warming Potential
The ratio of the warming caused by a substance to the warming caused by a similar mass of carbon dioxide.

Ozone-Depletion Potential
The ratio of the impact on ozone of a chemical compared to the impact of a similar mass of CFC-11.

Ozone-Depleting Substances
Those chemicals that contribute to stratospheric ozone depletion, including chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons, methyl bromide, carbon tetrachloride and methyl chloroform.

Central DDC System
- Schedules start/stop
- Optimum start/stop
- Duty cycling
- Load shedding
- Demand limiting
- Enthalpy economizer
- Temperature set back
- Supply air settings
- Water temperature settings
- Chiller optimization
- Chiller demand limiting
- Lighting systems control
- Security systems control
- Critical and maintenance alarms

These systems can be started, stopped and otherwise controlled for maximum efficiency. Alarms will feed back to a central console so that the condition of all equipment can be assessed at all times. As the actual building operating characteristics are established, the system operators will be able to make adjustments to operating set points to optimize system performance and reduce energy usage. A telephone interface module (TIM) allows for modem interface and touch tone overrides from any touch tone telephone. Wall thermostats provide office and lab occupants with digital readings of temperatures within the office suites. Occupants can request adjustments with a phone call to the building automation system operator.

Building Commissioning

In the past, commissioning has been used primarily as a procedure to verify the performance of HVAC equipment. It ensures that equipment is installed and operating properly before the building is occupied. Studies have shown that buildings that are not properly commissioned can lose as much as 20 percent of their operational energy efficiency due to improperly operating systems.

"Full systems" commissioning is becoming increasingly common. At the EPA facility, operators and maintenance personnel have been included in the commissioning process to enhance their understanding of the building's systems and their intended performance. Participants have included EPA personnel such as the building engineers, HVAC operation and maintenance personnel and building security personnel. A separate testing and start-up procedure was required for the DDC system to ensure that it is working properly and building engineers know how to operate it.

Systems to be Commissioned

- Each HVAC supply air system
- Each HVAC exhaust air system
- HVAC hot water system
- HVAC chilled water system
- HVAC HTHW system
- HVAC steam system
- Fuel oil system
- Animal watering system
- Water heaters
- Fire pumps
- Raceway system
- Conductor system and wiring devices
- Grounding system
- Lighting control system
- Fire and voice alarm system
- Security system
- Emergency stand-by power system

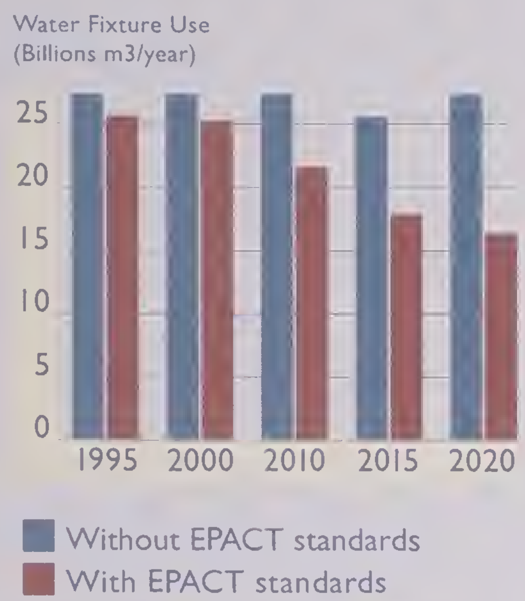
Building Acceptance Test Manual

A Building Acceptance Test Manual was developed by the project team to provide an operations manual for the building owner to use during commissioning and occupancy. All building systems–HVAC, electrical, fire safety, security, communications and architectural–were itemized and appropriate testing protocols were identified. This document serves as an important guide for ongoing maintenance and recommissioning over time.

Summary of major heating, ventilation and air conditioning systems.

Item	Impact on Energy Efficiency
Variable Speed Drives	Variable speed drives have been provided for all water pumps and air handling units. Sensors in the piping or duct system record fluctuations in static pressure or water pressure and transmit a signal back to the variable speed drives, which then slow down or increase the motor speed.
VAV Boxes in Office Areas	A standard Variable Air Volume (VAV) System is provided for the office spaces. A variable speed drive on the air handler will slow down the fan, thereby maintaining minimum system pressure and saving fan energy
Air Economizer Cycle	Each air handling unit for the office space is equipped with a free cooling economizer cycle. The air handling unit will operate at 100% outdoor air mode when the outdoor air temperature is below the space return air temperature. When the temperature drops, the system would then mix outdoor air and return air in order to maintain temperature.
Lab Air Handling Units - Optimum Operating Efficiency	Each of the main lab buildings contains five air handling units. As the building load increases, the control sequences will have the units operate at 60%, 80% and then 100% to optimize efficiency
Pipe Sizing	Piping has been sized so that the pressure drop is below the recommended values in Standard 90.1 Section 9.5.5.1, creating greater energy savings than required by ASHRAE or the applicable building codes.
Two Position VAV for Laboratories	Two-position air flow control for the laboratories: when the fume hood is at maximum flow, the box is fully open to provide 1120 CFM exhaust. If the lab is unoccupied and the hood sash is closed, the boxes will go to a 50% position, saving energy by reducing the air handling unit flow rate.
Building Infiltration Controls	By ensuring that pressurization exists, outside air infiltration is minimized to reduce loading on the heating system.
HVAC Control System	A direct digital control (DDC) central building automation system will monitor and control all equipment set points to maximize efficiency and monitor performance.
Air Filter Pressure	Static pressure sensors for each filter bank in all air handling units monitor pressure drop across filters and alert maintenance staff as when they need to be changed, thereby improving energy efficiency of fans.
Ductwork and Pipe Insulation	Meets the ASHRAE Energy Conservation Standard 90.1 requirements.
High Temperature Hot Water/Domestic Water Generation	High temperature hot water is circulated through heat exchangers to generate steam and also to make domestic hot water. This means that more of the energy per gallon of water is utilized and not wasted as system losses in the site distribution.
Water Atomizing Humidification	A water atomizing system for humidification has been incorporated into the laboratories and office spaces. Also serves as an evaporative cooling medium.

United States Projected Water Savings from Efficiency Standards



Source: Worldwatch Institute, 1996

Key Issues to Consider

- Meet or exceed the EPACT fixture requirements for water conservation
- Consider automatic shut-off faucets in high-use areas
- Consider alternative toilets and urinals
- Eliminate the use of chillers that use "one pass" water
- Explore water-efficient cooling tower options, such as drift eliminators and automated blow down

Water Conservation

Building operations consume an estimated 16 percent of the fresh water in the United States.[8] The portion used for landscape irrigation can be controlled through the use of native plantings and water reuse strategies. The water usage for equipment will vary based on the types of systems used, with one-pass cooling and evaporative strategies using the largest quantities of water. While water usage for plumbing fixtures has been reduced considerably due to the mandatory water efficiency requirements in the Energy Policy Act of 1992 (EPACT), more can be done to promote water conservation.

Water Conserving Fixtures

The EPA Campus uses EPACT standard low flush toilets and urinals. Lavatories used for hand washing have been demonstrated to perform quite well at 0.5 gallons per minute, instead of the 2.5 allowed by the EPACT. Consequently, aerators and flow restricting nozzles for faucets and showers were used to make the facility more

1992 Energy Policy Act (EPACT) Requirements for Water Conserving Fixtures, effective 1/1/94

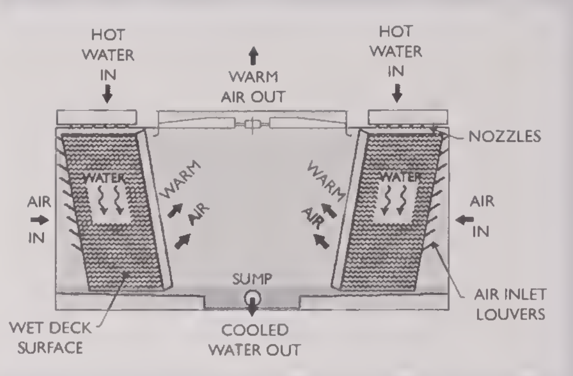
Shower Heads and Faucets Fixture Type	**Maximum Water Use**
Showerheads, any type (excluding safety showers)	2.5 gallons per minute
Lavatory faucets	2.5 gallons per minute
Lavatory replacement aerators	2.5 gallons per minute
Kitchen faucets	2.5 gallons per minute
Kitchen replacement aerators	2.5 gallons per minute
Metering faucets	.25 gallon per cycle

Water Closets and Urinals Fixture Type	**Maximum Water Use**
Gravity tank-type toilets (non commercial)	1.6 gallons per flush
Gravity tank-type toilets (commercial)	1.6 gallons per flush
Flushometer tank toilets	1.6 gallons per flush
Electromechanical hydraulic toilets	1.6 gallons per flush
Blowout toilets	3.5 gallons per flush
Urinals (any type)	1.0 gallons per flush

water efficient than the EPACT standard. For the EPA Campus, manual flush valves were used, and touchless "sensor-operated" lavatories provide for improved sanitation and heightened water conservation. Availability of hot and cold water has been improved by a recirculating system with automatic temperature controls.

Water Efficient Cooling Towers

Cooling towers provide an efficient complement to chilled water cooling systems, by rejecting the waste heat from the recirculating chilled water system. These towers maximize the surface area contact between outdoor air and the warm waste water, creating cooling action through evaporation. They have been made more water efficient by limiting "drift," or excessive water content, in the hot air that is rejected, and by recirculating the condensate water. Most, but not all, cooling tower manufacturers have incorporated drift eliminators as standard features that decrease water consumption.



Cooling tower

Cooling towers, however, must be protected from corrosion and contamination. Typically, this is done with chemical additives. The type and the quantity of additive used to treat the water varies regionally due to natural variations in the water chemistry. Generally, these additives include corrosion inhibitors, dispersants, algae and bacteria control agents, alkaline additives and oxygen scavengers. To determine the correct amount of a given additive for a specific cooling tower, periodic water tests are performed. The tests enable the development and regulation of a maintenance program with an automated system that controls dosage and "blowdown." Blowdown is the term for water that is discharged from the condensate water system to control the concentration of chemicals, salts and other impurities in the circulating water.

Cooling Towers Save Water
The EPA campus uses innovative features that will save about 4 million gallons of water per year.

The EPA Campus has incorporated some innovative features to improve the water efficiency of cooling towers, generating an estimated savings of approximately four million gallons a year. These features include a dynamic water analysis system that allows the quantity of blowdown to be reduced to a minimum. The system regularly monitors water quality, allowing better control of the additive dosage and thereby reducing the need to apply a "safety factor" in anticipation of days when the water quality may be atypical. The dynamic sampling system increases the cycles of concentration from 6-8, which is the industry standard, to 12-14. While the system conserves water, it also reduces reliance on chemicals and has a two- to three-year payback.

Ozone Treatment for Cooling Towers

An ozone system was considered early on by the project team as a nearly chemical-free option for treating condensate water in the cooling towers. The ozone system offered an attractive option because it not only conserved water, but it also greatly reduced reliance on chemicals for water treatment. Unfortunately, the system could not be cost justified for this application. The first cost premium for the system was estimated at $300,000–350,000, and the system also had higher maintenance costs.

Alternative Technologies

Alternative technologies were defined by the EPA project team as those that are not yet common in the marketplace. Some technologies were included in this category because they are new. Others were included even though they had not yet gained widespread acceptance because they only proved cost effective where rates for electricity, water or sewage treatment have become especially high. This was a subjective judgment that is not based on the merit of the individual technologies. Though all of the alternative technologies considered for the EPA Campus had positive environmental characteristics, most would have come at a significant cost

Key Issues to Consider

- Optimize energy and water-efficiency of standard facility design and systems
- Determine total resulting energy and water-use needs, including daily and seasonal variations
- Gather data on local and micro-climate, including solar incidence, average monthly temperature, wind patterns, relative humidity and average monthly rainfall
- Research currently available technologies for hydrogen fuel cells, wind power, photo voltaics, solar water heating, point of use water heating, grey water recycling, rainwater catchment and pervious paving
- Determine cost effectiveness of each alternative technology explored
- Investigate local, state and federal financial incentive pro grams for alternative technologies

Photovoltaics (PV)

Solid state semiconductor devices that convert light directly into electricity. They are usually made of layers of silicon or other semiconductor material with traces of other elements. PV cells are housed and wired together in "modules," which may be used singly or grouped in an "array." PV systems may include battery storage or may be wired directly to the utility line, although some systems may use neither. Systems with batteries need electronic devices to control their charging or limit their discharging of the batteries.

premium. In the interest of balancing environmental benefits with cost and functional performance, EPA chose to use only those alternative technologies which were most appropriate for this project.

It should be noted that the determination of cost effectiveness for some technologies was greatly impacted by the costs of electricity in RTP. Electricity costs vary widely across the U.S. At the current commercial rate in RTP of 4-5 cents per a kilowatt-hour (KWH), the cost of electricity is low. For example, rates in New York City or Boston are closer to 12-13 cents per KWH. While the low rate keeps the cost of operations down, it proved to be a disincentive to incorporating energy-efficient technologies that have marginal cost benefits.

Photovoltaics

Photovoltaics, or solar electric cells, convert sunlight into electricity. Many different types of technologies are available, but the two basic types are polycrystalline and thin film. The polycrystalline options are generally more efficient and more expensive than thin film options.

Photovoltaics were evaluated for the EPA Campus. However, working with a limited construction budget, the project could not bear the full first cost of photovoltaic electric systems for the entire campus. By exploring alternative funding strategies, the project team was able to incorporate two photovoltaic applications onto the campus.

Aided by grant funds from the federal Department of Energy and the State of Virginia, EPA chose to install a 100 kilowatt array on the roof of the National Computer Center building. This solar array provides power directly to the building. Since the building houses extensive computing systems, and has an unusually high power demand, the building is also connected to the electrical grid.

EPA also negotiated a lease-purchase arrangement with the local power company to install 70 photovoltaic lights along the site roadways–creating one of the largest solar road lighting projects in the U.S. Since the lights would be owned by the power company, prior to an optional buyout by EPA, the power company took advantage of a 35% tax credit from the State of North Carolina for solar power equipment purchases. The tax credit significantly reduced the cost of the solar lights to make the system cost-justifiable for EPA. Over a 20-year life cycle, EPA expects these solar lights to cost the same as standard street lights.

Fuel Cells

Fuel cells are highly efficient engines that convert natural gas into heat energy and electricity. For building applications, they are most appropriately used where there is a constant demand for electricity and heat 24 hours a day. Because of the size and weight of fuel cells, they need to be integrated into early conceptual planning to be accommodated successfully. In 1992-93, when the EPA Campus was in the early stages of design, fuel cells were not a viable option and were ruled out. They were later considered for the National Computer Center as a source for conditioned power and a replacement for the uninterruptible power supply, but again proved cost prohibitive. However, fuel cells have evolved rapidly over the past decade, and should be considered as a possible cost-effective source for large constant loads.

Wind Power

Wind generators are becoming increasingly prevalent in some parts of the country. They were determined to be inappropriate for the EPA Campus because of the forested nature of the site, the relatively low wind velocities in the area, and the

abundant low-cost electricity available on the site. Trees would have to be cleared to make room for wind generators on the site and this would have defeated the effort to minimize habitat disruption.

Solar Hot Water

Solar hot water technology provides an efficient application of the sun's energy to directly heat water for use. Given the low local cost of electricity, solar hot water heating offered the most likely cost-effective solar alternative. However, the central water system proposed for use on the EPA Campus was also very efficient and made use of heat recovery. Consequently, solar hot water generation was never formally evaluated.

Central Hot Water vs. Point-of-Use Hot Water

Point-of-use heaters for water can be an attractive option because heat is only generated when it is needed and heat energy is not lost in transmission as hot water is pumped and recirculated through the building. A study completed for the EPA facility to evaluate the potential benefit of using a point-of-use system for water heating made a clear case for the use of the central system. While the first cost of the point-of-use system is slightly lower, the life cycle costs are dramatically higher, since these systems are less efficient than a central hot water system. Heat recovery is more easily accommodated into a central system and maintenance is simpler when fewer pieces of equipment require servicing.

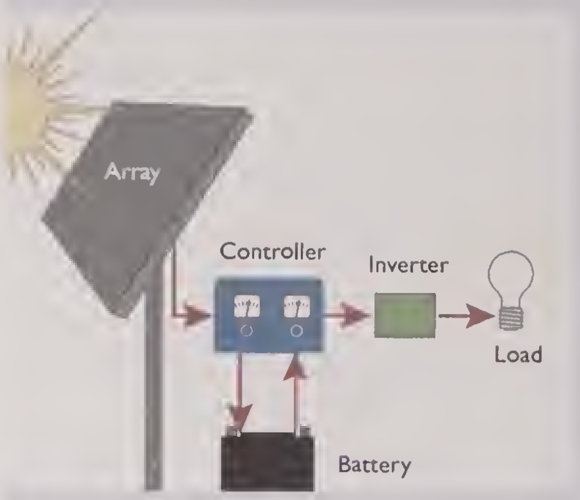
Point-of-Use versus Central Hot Water Heating

	Central Hot Water Plan	**Point of Use** 10 Year Warranty	**Point of Use** 20 Year Warranty
Hot water piping system	$140,694.90	$20,744.00	$20,744.00
Water heaters	$65,400.00	$109,156.00	$148,900.00
Miscellaneous installation	$1,600.00	$20,250.00	$20,250.00
Annual energy cost	$13,172.78	$46,147.76	$34,802.94
Annual maintenance cost	$6,700.00	$19,996.52	$16,330.00
Total 20-year cost	**$799,468.13**	**$2,151,799.00**	**$1,744,534.74**

Grey Water Reuse

Grey water is defined as all wastewater not originating from toilets or urinals. It includes water from lavatories, coffee sinks, showers and drinking fountains. The grey water study for the EPA Campus considered reuse of various sources of grey water ranging from the highly purified reverse osmosis (RO) water used in laboratories through the condensate from air handlers, and eventually to all the possible grey water sources combined. North Carolina codes restrict grey water use within the building, and the EPA's outdoor irrigation requirements were minimal. An option that treated black water (water from flushing fixtures) was also considered.

One interesting discovery from this study, however, was that there were nearly enough relatively clean water sources to provide the entire water requirement for flushing and irrigation without any need to introduce expensive filtration systems for water reuse of wastewater streams that would contains soaps and other contaminants. The water generated from condensate alone is 500-3,100 gallons per hour during the cooling season.



Typical PV system including battery and controller, Solarex

Fuel Cell
A fuel cell converts chemical energy directly into electricity via a modified oxidation process; that is, by reversing electrolysis. By combining hydrogen and oxygen from an outside source, the fuel cell makes electricity like a battery that does not need to be recharged because the fuel comes from outside. The process also produces heat, water and carbon dioxide depending upon the fuel used.

Solar Water Heater
A system in which direct heat from the sun is absorbed by collectors and transferred by pumps to a storage unit. Typically, the heated fluid in the storage unit conveys its heat to the building's hot water via a heat exchanger. Controls are needed to regulate the operation.

Point-of-Use Water Heater
A small water heater that services only the water to be used at one location, such as a single lavatory faucet, rather than storing hot water in a central tank and distributing it throughout the building via pipes, from which much of the heat will escape. Some point-of-use water heaters are "tankless," while others use very small storage tanks at each location.

Grey Water Recycling
Any system of reusing wastewater not originating from toilets or urinals. In commercial buildings this includes waste water from lavatories, showers, drinking fountains and janitor's sinks. Sometimes it includes stormwater. Grey water may be reused once to flush a toilet before being sent to sewage treatment or may be diverted to an irrigation system, depending upon its contaminants.

Rainwater Catchment
A system that gathers rain that falls on a roof or yard and channels it to a storage tank (cistern). The first wash of water on a roof is usually discarded and the subsequent rainfall is captured for use if the system is being used for potable water. Alternatively, a sand filter may be used.

Key Issues to Consider
- Gather data to evaluate life-cycle impact of materials and systems
- Balance environmental performance with cost and durability
- Dimension materials carefully to minimize waste
- Avoid the unnecessary use of finish materials
- Design for disassembly and reuse of materials
- Establish maximum volatile organic compound (VOC) content levels
- Establish minimum recycled content levels

Grey Water Reuse Study

	Option 1 Reuse RO reject only	**Option 2** Reuse all pure water waste streams	**Option 3** Option 2 plus clear condensate from air handlers	**Option 4** Option 2 plus grey water	**Option 5** Option 4 plus black water reuse
First Cost Premium	$70,940	$147,700	$409,500	$744,400	$1,480,000
Annual Costs [1]	$6,500/yr	$7,400/yr	$11,600/yr	$26,800/yr	$68,800/yr
Annual Water Savings	$6,380/yr	$15,000/yr	$23,000/yr	$27,200/yr	$29,100/yr
Payback	**N/A**	**19.4 years**	**35.9 years**	**1860 years**	**N/A**

[1] Annual costs refers to annual energy and maintenance costs

With minimal need for irrigation and restrictive codes for indoor use, along with a very high cost for dual plumbing systems, EPA opted not to include grey water reuse in the project.

Rain Water Catchment

Rain water catchment refers to systems that collect rain water in storage tanks or cisterns for reuse in the building or for irrigation. This was viewed as a landscape irrigation feature, and because nearly all irrigation requirements had been eliminated from the design, this option did not receive a formal investigation. Rain cisterns were considered as a possibility but were quickly eliminated due to code constraints for indoor use and little need for outdoor watering.

Building Materials

Through their design decisions and specifications, architects and engineers directly influence the purchase of millions of tons of materials each year. These design decisions impact the marketplace and influence the kinds of products that industry produces. In turn, these market decisions affect the selection of raw materials, the use of energy and water, the depletion of non-renewable resources and the creation of waste and pollution.

The project team for the EPA Campus considered the environmental impact of building materials over their entire life cycle in selecting materials for the new facility. Then, as the specifications were developed, specific performance criteria were documented to the greatest extent possible.

Life-Cycle Impacts of Materials and Products

Most standard building materials and products have a fairly wide field of manufacturers and, consequently, products vary. Therefore, selecting environmentally preferable building materials and products requires a proactive approach that examines the environmental and health impact of a product at each stage of its life cycle.

- **Raw Material Composition**
  Are the materials nontoxic? Renewable? Salvaged? From a sustainable source? Do they contain recycled content?
- **Production Process**
  How much energy and water is used in the manufacturing process? How much solid, aqueous and gaseous waste is emitted? Is manufacturing waste reused? Is the manufacturing plant energy efficient? Does the manufacturing plant conserve or reuse water?
- **Packing and Shipping**
  Is the product locally manufactured? Is minimal, reusable or recycled packaging used? Are efficient shipping methods used?
- **Installation and Use**
  How durable is the product? Can it be repaired? Is the installation method hazardous? Does the product, or related adhesives or finishes, produce chemical emissions? Is the product low maintenance? Do maintenance procedures produce chemical emissions?
- **Resource Recovery**
  Is the product salvageable, recyclable or biodegradable? Does the manufacturer have a take-back program?

Durable Materials

EPA's long-term commitment to its new facility and its location in RTP is reflected in the stated design goal to create a "100-year-building." This view is intended to reduce long-term operating and maintenance costs. Highly durable materials have an environmental advantage because fewer materials are used over time and less material is disposed of. Examples of durable materials selected for the facility include cementitious terrazzo, mud-set ceramic tiles and the precast concrete exterior wall system. The ceramic tile will last almost forever when properly installed, and the cladding is anchored to masonry backup walls, detailed with stainless steel flashing, and sealed to enhance longevity and maintainability.

Recycled Content

Specification of materials with recycled content helps to conserve virgin resources and drives the market for recycling. Therefore, the specification for the EPA facility included detailed requirements for minimum recycled content by material type. The EPA's Recovered Materials Advisory Notices (RMAN) provided preliminary guidance. Then, research into market availability was performed using a detailed questionnaire. The goal was to evaluate the cross-section of products available so a competitive range of manufacturers could be selected.

Products specified with recycled content include rubber flooring, ceramic tiles, asphalt paving, cast-in-place concrete, insulation, wood fiberboard, gypsum wallboard and more. The following figure presents all of the recycled content provisions in the final specification. The list represents minimums and many materials have been procured that contain more than the minimum required. The following chart summarizes the improvement that the specification represents compared to standard practice for many of the material types.

During construction, EPA was unable to find local asphalt plants that could produce 25% recycled content asphalt as designed. The quality of the specified asphalt from plants unfamiliar with this production became a concern. As an alternative, EPA accepted asphalt with slightly lower recycled content which incorporated roofing shingle scrap–a waste that is typically difficult to recycle.

Palette of finish materials used in the main facility

Sample of EPA Campus Materials

- 4 acres of concrete block walls
- 2 acres of Low-E glass
- 35 acres of drywall
- 7 acres of carpet
- 12 acres of ceiling tile
- 2,861 interior doors
- 19 miles of telcom conduit

What is RMAN?

RMAN stands for Recovered Materials Advisory Notice. It provides guidance on recycled content materials and was issued by the EPA in May 1995. Construction materials include:

- Cement and concrete containing fly ash (previously issued January 28,1993 as 48 FR 4230)
- Building Insulation (previously issued February 17, 1989 as 54 FR 7327)
- Structural fiberboard
- Laminate paperboard
- Plastic pipe and fittings
- Geotextiles
- Cement/concrete using ground granulated blast furnace slag
- Carpet
- Floor tiles
- Patio blocks
- Hydromulch

RMAN Update
An update was issued in November 1997, that added the following construction materials categories:
- Latex paint
- Shower and toilet partitions
- Parking stops

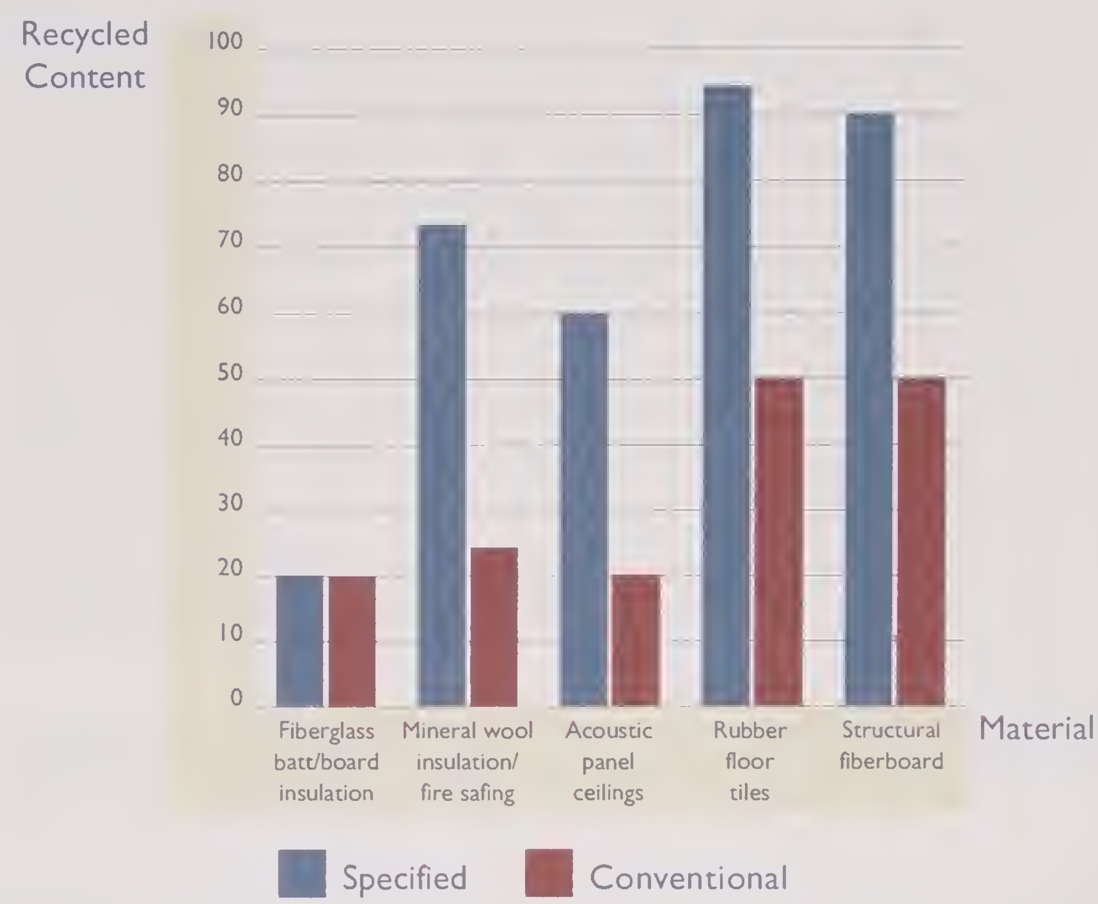
How is RMAN Enforced?
Once the EPA designates items that are or can be made with recycled content, RCRA section 6002 requires any procuring agency when using appropriated federal funds to use the highest percentage of recovered material practical.

Pre-Consumer Waste (aka in-plant-scrap)
Comes from material off-cutting, damaged material or other manufacturing waste.

Post-Consumer Waste
Comes from products discarded by end users (consumers). Examples include newspapers, magazines, beverage containers, building materials, etc.

Renewable Materials
Are replenished at a rate equal to or greater than their rate of depletion.

Heavy Metals
Includes mercury, lead, cadmium, thallium, cobalt, nickel and aluminum. Most are very toxic and persistent in the environment.



Comparison of Recycled Content Levels Specified with Conventional Materials

Minimum Required Recycled Content

Material or Product	Recommended Recycled Content
Asphaltic concrete paving	25% by weight [1]
Reinforcing steel in concrete	60% recycled scrap steel [2]
Reinforcing bars in precast concrete	60% recycled steel [2]
Concrete masonry unit	50% recycled content
Reinforcing bars in concrete unit masonry	60% recycled steel [2]
Framing steel	30% recycled steel [2]
Fiberglass batt insulation	20% recycled glass cullet [3]
Fiberglass board insulation	20% recycled glass cullet [3]
Mineral wool insulation	75% recycled material (slag) [3]
Mineral wool fire safing insulation	75% recycled material by weight (slag) [3]
Gypsum board	10% recycled or synthetic gypsum
Facing paper of gypsum board	100% recycled newsprint including post consumer waste [3]
Mineral fiber sound attenuation blankets	75% recovered material by weight (slag) [3]
Steel studs, runners, channels	60% recycled steel [2]
Acoustic panel ceilings	60% recycled material by weight
Ceiling suspension systems	60% recycled material
Rubber floor tiles	90-100% recycled materials [3]
Hydromulch	100% recovered materials [3]
Structural fiberboard	80-100% recycled content [3]

[1] As per North Carolina Department of Transportation (NCDOT) recommendation.
[2] 60% represents the average recycled content for the U.S. steel industry. Use of U.S. manufactured steel will meet this requirement.
[3] As per EPA Comprehensive Guideline for Procurement of Products Containing Recovered Materials (60 FR 21370, effective 5/1/95) and its corresponding Recovered Materials Advisory Notice (RMAN), 5/1/95.

Local Materials

Many materials selected for the EPA Campus were locally manufactured including concrete, brick pavers, concrete masonry block and precast wall panels. The specification of local materials was a good environmental choice because, all other things being equal, it minimized energy use and the pollutants generated during transportation. Local materials also are generally less costly and have shorter lead times than alternatives that need to be shipped long distances.

Consideration of local markets also affected the development of the specifications in a more general way. As environmental specification requirements such as minimum recycled content were being developed, the project team researched the potential for local manufacturers to meet those requirements. The team did not want products, especially bulky materials such as drywall, to be shipped from remote locations just to satisfy an extreme environmental requirement. Consequently, trade-offs were made and the final design specifications reflected those products in the local market with better-than-average environmental performance.

Low Toxic and Low VOC Materials

Volatile organic compounds (VOCs) are carbon-based chemicals which are in a gaseous phase at ambient temperatures. VOCs can include irritants and some carcinogens that are commonly found in building materials. VOCs are emitted from these materials as a result of the selection of raw materials and intermediate chemicals used in manufacturing processes.

EPA specifications require low-VOC adhesives, finishes, sealants, joint compounds and paints. See the following figure for a complete listing of requirements. Certifications were also required to document that no heavy metals were present in paints, adhesives and sealants.

For the building occupant, the concern over VOCs involves the extent to which they are "off-gassed" into the indoor air from a specific material. VOCs for liquid-based products can be measured in grams per liter (g/L). Grams per liter represents the total quantity of VOCs in the material; the volatility of the material determines how quickly they will evaporate from the material surface.

Material selection to reduce VOCs in the building interior is an excellent way to practice pollution prevention. Many commonly used products have been reformulated to be water-based instead of solvent-based. Simply reducing the quantity of solvents can lead to performance problems, as was the case when the first generation of low-VOC paints and adhesives was developed. However, many of the reformulated products today are equal to or superior to their conventional solvent-based counterparts. For example, a good quality, high-performance acrylic latex paint can outperform the conventional alkyd enamel that has typically been used for high-wear applications in all categories of performance: hardness, abrasion resistance and washability. With the myriad of options that exist for paints and coatings (which are constantly changing), it is extremely important to research the available options and reference performance standards when specifying.

VOCs
(Volatile Organic Compounds)
Chemicals that are carbon-based and evaporate from material surfaces into indoor air at normal room temperatures (referred to as off-gassing).

Performance Standards for Paint

The durability of paints and coatings is a critical factor of their total life-cycle impact: low-toxic paints that require additional coats to cover or that must be re-coated more often than conventional products have lesser overall environmental advantages.

Applicable Testing Standards for Interior Paint Performance

- ASTM D2486-89 for scrubbability (abrasion resistance)
- ASTM D2805-88 for hiding power (opacity)
- ASTM D3359-90 Method B for washability (stain resistance)

Low-VOC Content Requirements

Material or Product	VOC Content (Grams/Liter)
Form Release Agents	350
Plastic Laminate Adhesive	20
Casework and Millwork Adhesives	20
Transparent Wood Finish Systems	350
Cast Resin Countertop Silicone Sealant	20
Garage Deck Sealer	600
Water Based Joint Sealants	50
Non-Water Based Joint Sealants	350
Portland Cement Plaster	20
Gypsum Drywall Joint Compound	20
Terrazzo Sealer	250
Acoustic Panel Ceiling Finish	50
Resilient Tile Flooring Adhesive	100
Vinyl Flooring Adhesives	100
Carpet Adhesive	50
Carpet Seam Sealer	50
Water Based Paint & Multicolor Finish Coatings	150
Solvent Based Paint	380
Performance Water Based Acrylic Coatings	250
Pigmented Acrylic Sealers	250
Catalyzed Epoxy Coatings	250
High Performance Silicone	250
Casement Sealant	50
Liquid Membrane-forming Curing & Sealing Compound	350

Sustainably Harvested Wood

Wood was used in very limited quantities as an accent material in the new facility. In addition, all finished wood millwork and paneling was specified to come from a certified sustainable source. All of the species specified are domestic hardwoods. Wood that was used has been mounted with clips that allow for future removal and reuse as needed. When wood paneling was reviewed in value engineering, the team chose to maintain the aesthetic qualities of wood in the design, but opted to use half as much as originally intended.

Resource Recovery

The impact of resource recovery was addressed throughout the material selection and detailing process. The objective was to enhance the potential for future recyclability, reuse or salvage. If these options proved impractical, then the potential for enhanced biodegradability was considered. Use of metals without alloys, mechanical fastening of wood panels and specification of certified recyclable carpeting are examples of ways that recycling was encouraged. With a facility that will use more than seven acres of carpet, the team believed it was very important to be certain that the material could be returned for recycling at the end of its life.

Site Materials

When working on a 133-acre site with a building footprint of more than 10 acres, the quantities of material generated during site clearing, excavation, roadwork and landscaping can become significant. Consequently, every effort was made to consider the site when thinking about environmentally preferable materials. Reuse of on-site material proved to be an especially sound environmental initiative because it conserved resources and eliminated waste at the same time. All land-clearing debris was shredded for use as landscaping mulch or as a soil amendment. Excavated rock was crushed for use as fill material. The project team also found opportunities to use large quantities of recycled materials. For example, concrete aggregate and recycled asphalt are used in the roadwork, and the hydromulch is a 100 percent recycled cellulosic or wood product.

Government Procurement Requirements

Government procurement rules require that a minimum of three products be capable of meeting the specification to ensure a competitive bid. While it is good practice to ensure competitive bidding on all projects–not just for government contracts–it can limit the use of some emerging new "green" products. Although this proved to be a challenge for the EPA Campus project, designers were able to identify competitive sources for all materials specified.

Indoor Air Quality

The quality of indoor air delivered to the breathing zone can influence the health, comfort and workplace productivity of a building's occupants and visitors. To ensure that indoor air quality (IAQ) concerns were integrated throughout the design process, EPA made design for good IAQ a prominent issue in its request for proposals and in its design contract with the A/E. All significant program requirements, design criteria and design features were documented in an Indoor Air Quality Facility Operations Manual developed by the A/E team, which will provide guidance for the IAQ program in the occupied facility.

Source Control, Source Isolation and Source Dilution

Traditional methods of ensuring good indoor air quality rely almost exclusively on ventilation strategies. In these instances, fresh air is introduced into the space to

Certifying Sustainably Harvested Wood

The Forest Stewardship Council accredits agencies to certify forestry operations and chain-of-custody wood products distributors. Two major FSC-accredited agencies include Scientific Certification Systems and the Rainforest Alliance's Smartwood Program, which has a growing number of regional affiliates across the United States.

Key Issues to Consider

- Designate building a non-smoking facility
- Test for radon
- Require full-systems commissioning
- Adopt ASHRAE 55-1992
- Adopt ASHRAE 62-1989
- Locate intakes and exhaust to avoid re-entrainment
- Limit use of fibrous material exposed to the airstream, including duct liner
- Select "low-emission" materials
- Develop IAQ management plan for construction
- Designate an IAQ manager.
- Ventilate, but don't "bake out"

What is a VOC?
Volatile Organic Compounds (VOCs) are carbon-based chemicals that contain carbon molecules are volatile enough to evaporate or "off-gas" from materials surfaces into indoor air at normal room temperatures. VOCs include Methane, Ethane, Methylene Chloride, 1,1,1-Trichloroethane, CFCs, HCFCs, HFCs, Formaldehyde and other chemical compounds.

Source Control
Eliminates potential contaminants at the source, preventing their entry into the building.

Source Isolation
Physically separates potential sources of contamination from the airstream.

Source Dilution and Removal
Utilizes ventilation and filtration to dilute and remove contaminants in the airstream.

dilute contaminants that accumulate over time. A more proactive and cost-effective strategy involves a life cycle approach to indoor air quality. The EPA campus approach employs source control, source isolation, and source dilution for design and construction, together with an integrated IAQ management plan for the operations and maintenance phase.

Source control strategies eliminate possible sources of contamination before they are introduced into the building. Examples include designating a building as non-smoking, limiting the use of exposed friable fibrous materials which can become airborne, and avoiding possible sites of microbial growth. The judicious selection of building materials can minimize emissions of VOCs, toxic chemicals and other irritating substances.

Source isolation strategies control sources of contamination that cannot be completely eliminated. Office buildings, for example, will contain copy machines, food preparation areas, loading docks and toilet rooms. In addition to these sources, the EPA Campus has chemical and biological laboratories that could pose significant risk to the air supply in the case of an accidental spill or release. All of these areas are separately ventilated to the outside so that exhaust air is not recirculated into the buildings. Building pressurization and appropriate location of building openings further reinforces source isolation. To ensure proper isolation of laboratory exhaust stacks from air intake vents, EPA built a scale model and ran a wind tunnel study to test worst-case atmospheric conditions. As a result of the study, the exhaust risers were extended 10 feet higher into the air.

Source dilution, the final method in the hierarchy of IAQ control strategies, refers to ventilation and filtration of building indoor air. Flexible design combined with commissioning at the end of construction ensures ventilation effectiveness. Temporary ventilation is used to purge the building of contaminants during construction. By ensuring ventilation effectiveness, indoor air quality is enhanced and energy efficiency is improved.

Designing for Indoor Air Quality

Factors that impact IAQ include outdoor air quality, site conditions, building and HVAC design, interior design, materials selection and construction procedures. Design for IAQ requires a strong dialogue between all members of the team. An IAQ advocate should be identified to champion IAQ issues in project team work sessions. An IAQ manager also should be identified on the owners team to track issues as design and construction progress, and to help manage the IAQ program in the completed facility.

IAQ Facilities Operation Manual

The EPA project team created the Indoor Air Quality Facilities Operation Manual to document design decisions that will impact IAQ throughout the life of the facility, so future building renovations will not undermine those features. This manual also describes IAQ-related construction provisions including IAQ testing of materials, sequence of finish installation, temporary ventilation, baseline IAQ testing and commissioning. Preprinted forms, including HVAC Equipment Inspection Forms and an IAQ Management Checklist were developed to guide building operators throughout the occupancy phase.

Indoor Air Quality vs. Energy Efficiency

The design team took great care to balance energy efficiency with good indoor air quality. While an abundant supply of fresh air with frequent air circulation will help promote good IAQ, it can be energy-intensive. The challenge for the EPA campus project was to strike a balance–optimizing IAQ performance without creating an excessive energy demand.

Fortunately, some strategies promote good IAQ while at the same time saving energy. For example, outside air economizers provide EPA's offices with "free cooling" when weather conditions are right. These economizers are digitally controlled and filter the outdoor air to remove mold spores, pollen and other contaminants while bringing in increased quantities of fresh air."

EPA's offices are conditioned with a simple, low-cost "straight" VAV system. This was deemed to be a better choice than a fan-powered VAV system, which uses more energy and demands more maintenance. Using indoor air modeling based on this system, the design team calculated the air circulation rates that would be required to meet ASHRAE recommendations for fresh air supply. In order to achieve ASHRAE's recommended minimum of 20 CFM outdoor air per person, the system could be set as low as only one air change per hour (ACH). But since air movement is just as important as fresh air in achieving good IAQ, the VAV system was set to a minimum of 2.25 air changes per hour (ACH)–about twice the minimum indicated by using the ASHRAE standard alone.

The office heating and air conditioning system has also been designed to constantly supply a minimum of 25% outdoor air. Based on actual demand, however, this percentage can be increased. Carbon dioxide monitors continually sample the air in return plenums to detect CO2 buildup in offices and meeting spaces. If levels are high, indicating increased human activity in the space and a higher demand for fresh air, the ventilation system will respond by bringing in more outside air. By preventing the excessive use of outdoor air and supplying more fresh air when needed, the CO2 monitoring approach will save energy while promoting healthy IAQ.

Low-Emission Materials

Chemicals present in building materials and products can lead to the off-gassing of substances that are irritants and, in some cases, even health hazards in the interior environment. Off-gassing is measured in emission rates or emission factors, which can vary significantly for similar materials by different manufacturers. Without testing, emission factors are difficult to ascertain. The EPA project team sought published reports of previous studies and some material manufacturers were willing to share testing data, however the information was still scarce.

In the absence of testing data, one of the few resources for evaluating chemical content is the Material Safety Data Sheet (MSDS) on which the manufacturer is required to list all chemical constituents making up at least one percent of the material, and not deemed "proprietary." For liquid-based materials such as paint and adhesives, the total concentration of VOCs is listed in grams per liter. However, the MSDS is limited in that the manufacturers may omit chemicals that they consider trade secrets, and the MSDS does not list compounds that result from reactions among the constituent chemicals.

IAQ Testing of Materials

IAQ testing and modeling gave the team an indication of what air quality would ultimately be like in the building. The purpose was to determine the composition and the rate of chemical emissions. The testing is typically conducted in either a large or a small-scale environmental chamber that has been carefully designed and instrumented. Using a predictive modeling tool developed by EPA staff called EXPOSURE, the emissions testing results were then used to predict the ultimate concentration of indoor air contaminants that would result over time, based on the anticipated ventilation rates.

Factors That Impact Indoor Air Quality

Outdoor Air Quality
- Building exhaust from adjacent buildings
- Vehicle exhaust from adjacent roadways
- Releases from adjacent industrial and agricultural sites
- Soil gas (radon)

Site Conditions
- Vehicle exhaust
- Pesticides and fertilizers
- Sporulating plants

Building and HVAC Design
- Location of fresh air intakes and exhaust
- Interior pollutant-generating sources, e.g., print rooms, loading docks
- Air and moisture flows through the exterior wall
- Fibrous insulation exposed to the airstream, e.g., internal duct liner
- Ventilation and filtration standards

Interior Design
- Air circulation
- Location of copy machines
- Housekeeping equipment and product storage

Materials Selection
- Fibrous materials
- Microbial contamination
- Emissions of VOCs
- Toxic components

Construction Procedures
- Proper installation and balancing of equipment
- The sink effect

IAQ Materials Testing
- Paint on gypsum board
- Carpet and adhesive
- Ceiling tile
- Fireproofing

The team established thresholds for the maximum allowable concentrations of contaminants in the indoor air, based on health effects research and an understanding of what is possible to achieve in a new building with materials commonly available in the market. These thresholds were used to screen selected finishes and as testing criteria for overall indoor air quality in the finished facility. At the end of construction, ambient air sampling and testing were required to be performed at 16 locations throughout the office areas of the new EPA facility.

Maximum Indoor Air Concentration Standards

Indoor Contaminants	Allowable Air Concentration Levels*
Carbon Monoxide (CO)	< 9 ppm
Carbon Dioxide (CO^2)	< 800 ppm
Airborne Mold and Mildew	Simultaneous indoor & outdoor readings
Formaldehyde	< 20 $\mu g/m^3$**
Total Volatile Organic Compounds (TVOC)	< 200 $\mu g/m^3$**
4 Phenylocyclohexene (4-PC)***	< 3 $\mu g/m^3$
Total Particulates (PM)	< 20 $\mu g/m^3$
Regulated Pollutants	< NAAQS
Other Pollutants	< 5% of TLV-TWA****

* All levels must be achieved prior to acceptance of building. The levels do not account for contributions from office furniture, occupants and occupant activity.
** Above outside air concentrations.
*** 4-PC is an odorous contaminant constituent in carpets with styrene-butadiene-latex rubber (SBR).
**** TLV - TWA = Threshold Limit Value - Time Weight Average.

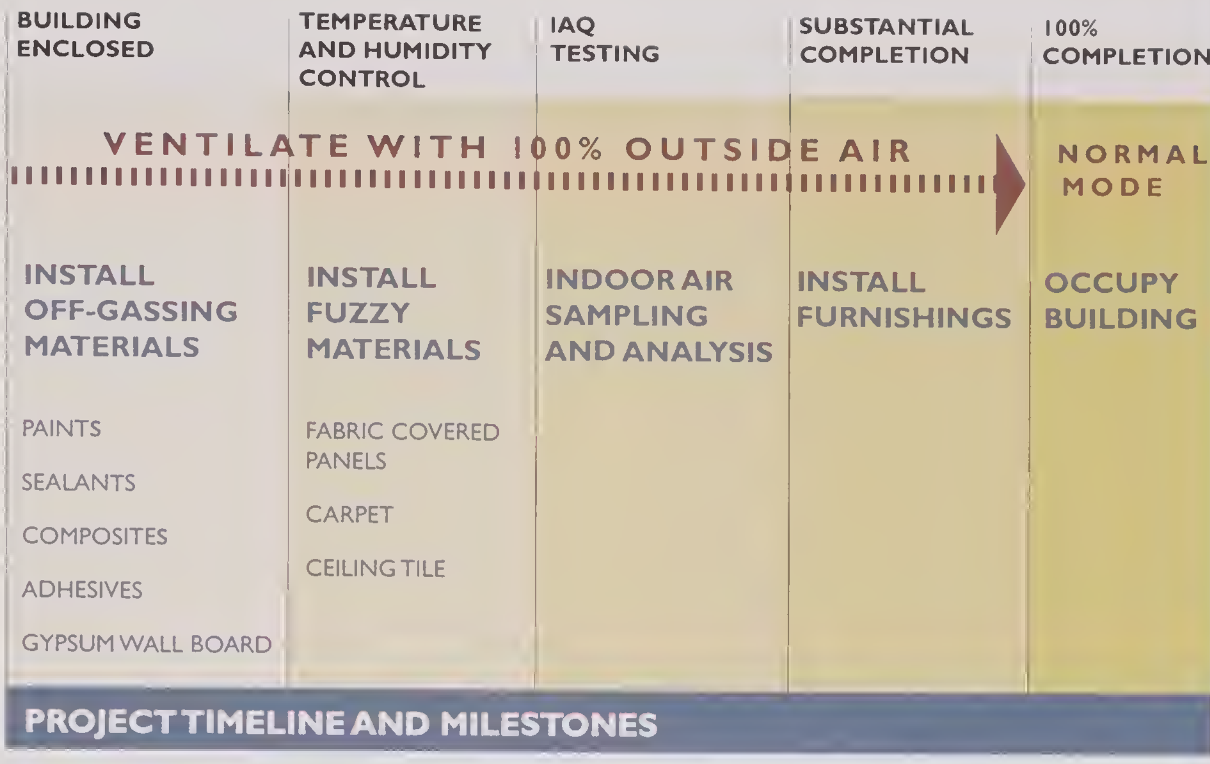
Natural Resource Building, Olympia, Washington
The Natural Resources Building (NRB) is a 300,000-square-foot, six-story office building completed in Washington state in 1992. During its design, construction and commissioning, three steps were taken to promote good IAQ:
- The HVAC system was designed to the requirements of ASHRAE 62-89
- To avoid potential high-emitting materials in the building, major materials used in the construction, finishing and furnishing of the building were required to be tested in an emission test chamber
- To allow all materials emissions to decay, the empty building was flushed out with 100% outside air for 90 days prior to occupancy

The project team originally specified that all materials used in large quantities with potential to impact indoor air quality be chamber-tested by the contractor, with results to be used by EPA to model predicted concentrations of chemicals. Based on concerns about the cost of this extensive testing program, however, the requirements were revised to focus on the four materials most commonly exposed to the air in the building. These four materials were required to be tested as they would be assembled in the building–paint applied to gypsum wallboard, carpet adhered to concrete, fireproofing spray on steel, and acoustical ceiling tile.

Construction Procedures

EPA specifications require many of the same IAQ-related construction procedures that were employed by the Natural Resources Building in Olympia, Washington. Some changes were made, however, based on the lessons learned in construction of the Washington project.

Prior to construction, the contractor for the EPA Campus was required to submit a schedule that described the sequence of material and finish installation. Construction sequencing recommended that "wet" materials that release indoor air contaminants as they cure, be applied before the installation of "fuzzy" materials that absorb airborne contaminants and re-emit them over time. Temporary ventilation during construction further protected the building from absorbing contaminants during the construction process. From the time the building was

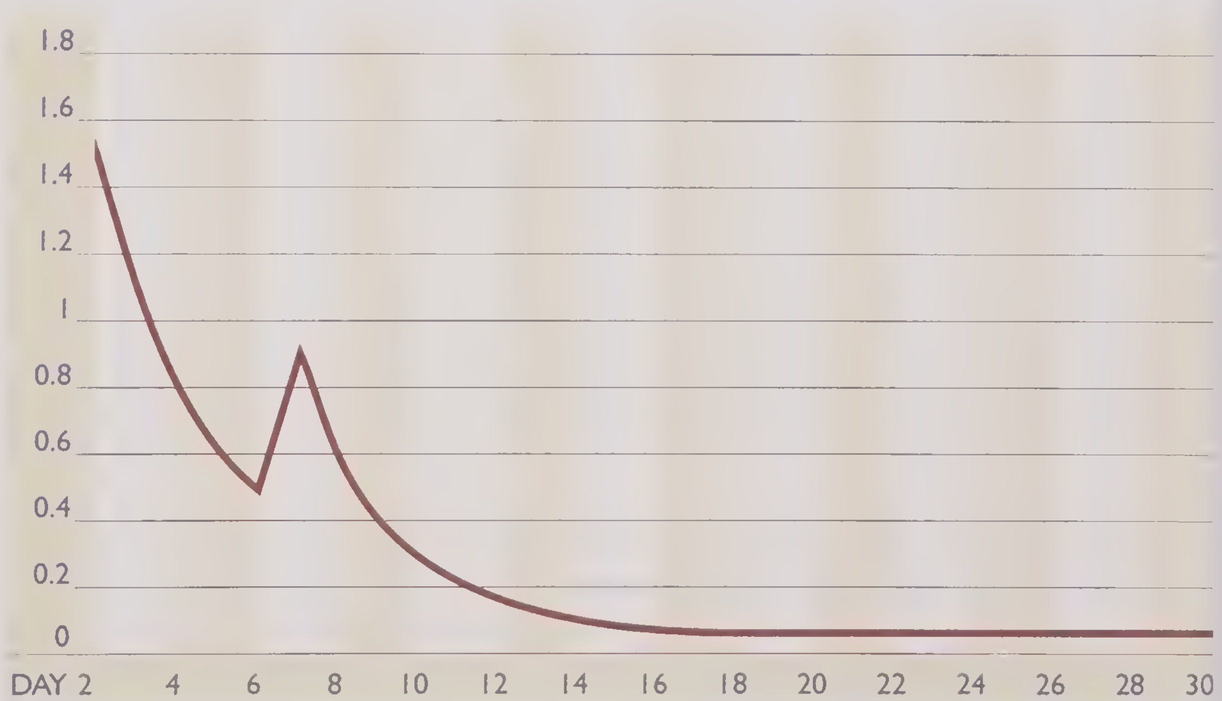


Generic Schedule Sequence of Finishes

substantially enclosed until occupancy, the building was required to be ventilated with 100 percent outside air. Any ductwork used during construction was required to be cleaned prior to occupancy.

The EPA project team used an alternative to the extended 90-day post-construction flush-out period that was employed by the Natural Resources Building. Specifications for the EPA Campus required the contractor to ventilate during construction and perform baseline indoor air quality testing prior to acceptance to determine whether indoor air concentrations comply with maximum allowable limits (see chart below). If materials are installed as specified and

Predicted TVOC Concentration During 30-Day Flush-Out



EXPOSURE Model
Modeling courtesy of Jason M. Cortell & Associates

What is the "Sink Effect"?

The sink effect refers to the absorption of chemicals by a surface, which slowly releases them into the building atmosphere over time. Finishes with the highest accessible surface area (e.g., "fuzzy" materials such as carpet, upholstery and ceiling tiles) per unit mass tend to have the highest sink effect.

Sequences of Finish Installation

Wet "off-gassing" materials must be installed before dry or fuzzy "sink" materials to the greatest extent possible.

"Wet" materials include, but are not limited to: adhesives, sealants, glazing compounds, particle board and paint.

"Dry" or fuzzy materials include, but are not limited to: carpet and padding, ceiling tiles and fabric-wrapped acoustical panels.

What is "Flush-Out"?

Flush-out refers to increased ventilation to remove, or "flush-out" contaminants from the building. Flush-out is best performed with 100% outside air that is exhausted directly to the outside and not recirculated. Scheduling of flush-outs during construction, pre-occupancy and before start-up after the systems have been down will enhance indoor air quality.

Why Not "Bake Out"

Running building at high temperatures post-construction to "bake" chemicals out could possibly cause unusual chemical or biological conditions, and is not recommended.

Indoor Air Quality Facility Operations Manual

- Offers guidance for provision and maintenance of IAQ for the new EPA Campus during construction, pre-occupancy and post-occupancy
- Documents the design criteria employed and major design decisions made
- Describes IAQ-related construction provisions including IAQ emissions testing of materials, sequence of finish installation, temporary ventilation, base-line IAQ testing and commissioning
- Contains HVAC equipment inspection forms, IAQ management checklist and other forms

Design Decisions Matrix

Item	Decision	Impact on IAQ
Siting of Building	Locate exhaust downwind from outside air intakes and separate by more than 100 feet.	Minimizes reentrainment of laboratory exhaust at air intakes.
	Maximize separation between parking areas and air intakes.	Reduces potential vehicular exhaust entering the building.
Location of Parking Garages	Locate parking structure away from the building.	Reduces the potential for vehicular exhaust entering the building
Laboratory Exhaust Stacks	Stack height increase to 30' based on wind tunnel testing.	Minimizes reentrainment of laboratory exhausts into air intakes.
Radon	Site specific testing confirmed low levels of radon.	Confirmed that radon levels are safe.
Delivery/Loading Zone	Maintain negative pressure in loading area, positive pressure in building.	Eliminates entrainment of delivery vehicle exhaust.
Landscaping	Low maintenance and non-sporulating plants selected.	Intake of spores, fertilizer or chemicals entering the building is reduced.
	Plants used as a barrier for vehicle exhaust.	Minimizes entrainment of vehicular exhaust.
Laboratory Fume Hoods	Install flow guages and alarms.	Provides warning of air contaminants present in laboratory areas due to loss of air flow.
Acoustical Insulation of Ducts	Ductwork increased in size to eliminate need for acoustical insulation. In select areas, mylar coated silencers are used as ductwork transitions out of equipment rooms.	Minimizes potential for release of fibers into the airstream and possible contamination of the HVAC system (duct liners are difficult to monitor and clean and can be sites of microbial contamination).
Moisture Accumulation	Install drain pans pitched toward drain pipe.	Reduces moisture, which could result in introduction of bacterial contamination into HVAC system.
Humidity Control	No moisture carry-over into system.	Minimizes moisture in HVAC system and resultant bacterial contaminants.
Corrosion Inhibitors	Inhibitors do not contain volatile amines.	Eliminates exposure to certain air contaminants.
Fireproofing Spray	Cementitious mix specified for return air plenum.	Helps minimize potential for airborne fibers.

ventilation is provided during construction, the building should pass the test shortly after the building construction is complete. See the EXPOSURE modeling on the following page for results of a study indicating the building VOC levels should fall within the acceptable range about 12 to 14 days after construction is complete. If limits were not met, the contractor would be required to ventilate the building until it met the required limits and bear the expense of retesting.

This EXPOSURE model predicted the concentration of VOC in the indoor air over a 30-day flush out period beginning after construction is complete. Furniture was projected to be installed on the 6th day after flush-out began, and VOCs reached acceptable levels by the 14 day. Although this analysis considered "typical" furniture available from the marketplace, EPA further extended its IAQ protections into furniture procurement. The products in EPA's new offices were, like the products used during construction, required to have low VOC and formaldehyde emissions.The IAQ Facility Operations Manual, developed by the EPA project team, includes a design decisions matrix outlining exterior and interior design components of the new campus and the impact these decisions had on IAQ.

Key Issues to Consider
- Adopt a philosophy of avoidance toward all risks to human health and well-being
- Predict EMF levels at different locations in the building; identify major sources
- Increase occupant distance from major sources of EMF
- Modify floor plan to buffer spaces of regular long-term use from major EMF sources
- Have soils tested for radon if building is located in a region where radon occurs
- If necessary, incorporate a radon mitigation system into the building design

Risk Prevention

Building-related health risks are often difficult to recognize prior to the scientific discoveries that provide a verifiable link to health effects. However, the high cost of asbestos and lead remediation has building owners, operators and occupants thinking carefully about how to avoid exposing themselves to similar financial risk from other building-related problems in the future. Consequently, the team for the EPA Campus carefully considered the potential risk associated with electromagnetic fields (EMFs) and radon gas.

Electromagnetic Fields

The team reviewed available literature on EMFs and their threat to health and determined that while EMF radiation could be measured, its threat to humans had not yet been proven or disproved. Nevertheless, the team recommended adopting a philosophy of prudent avoidance toward EMF risks and undertook modifications of the building design to reduce occupant exposure.

EMF radiation can be mitigated by distance and by shielding. Distance offers maximum protection and is "low-tech," while the costs associated with shielding are high and the results are difficult to measure. Consequently, the design team chose to create "buffer zones" to reduce prolonged exposures in portions of the building that are occupied for long periods of time, such as the laboratories and offices.

The largest sources of EMF were identified as the building's transformers, the electrical rooms with their many cables, and the electrical conduit that was routed under the building atria. As a first step circulation and utility spaces were used to maximize the separation between a source and any potential receptors. An analysis revealed that the conduit under the floor of the atrium would not be problematic because the time for possible exposure in that circulation space is minimal. However, the electrical rooms had to be relocated next to restrooms and utility spaces and away from occupied areas such as offices, laboratories or meeting spaces.
Because EMF radiation diminishes geometrically over distance, the floor of the main electrical room was lowered so that a separation of at least six feet could be made between the electrical transformers and building occupants on the office floor above. Research has shown that EMF exposures are minimal beyond a distance of six feet from the source.

Electromagnetic Fields (EMFs)
Electric and magnetic fields may occur alone or in combination and are a form of non-ionizing radiation. Electricity flowing in a wire or being used in an appliance creates electric and magnetic fields around them, as do power lines and electrical equipment used in commercial buildings.

Radon Prevention Measures Commonly Used in Commercial Buildings

- Active soil depressurization
- Pressurization of the building using the HVAC system
- Sealing all major radon entry routes

Radon Gas

Radon is a colorless, odorless radioactive gas produced by the radioactive decay of radium-226, an element found in varying concentrations in many soils and bedrock. As a gas, radon can easily move through small spaces between particles of soil and thus enter a building, reaching levels many times higher than outdoor levels.

Radon levels are usually measured in picocuries per liter of air (pCi/L). It is currently recommended that radon levels be reduced to less than 4 pCi/L, if not as close to ambient levels as feasible (0.4 pCi/L). The radiation released by the decay of radon isotopes can damage lung tissue and can increase one's risk of developing lung cancer. The health risk depends upon both the levels and the length of exposure to radon decay products.

Radon typically enters a building from the soil through pressure-driven transport, where the conditions in the building draw air up and into an opening. Radon can also enter a building through diffusion, well water and construction materials. While radon mitigation is an issue that most people associate with residential construction, the risks for commercial building occupants are real. Because radon gas is naturally occurring in the soils of some portions of North Carolina, EPA believed that it was prudent to have its site tested for radon gas. While EPA was prepared to take action if necessary, the tests proved that radon was not present on the site and that no mitigation was needed.

Key Issues

- Design in modules to minimize construction waste
- Develop construction waste recycling plan, including salvage of existing construction materials
- Mulch landscape debris and other organic waste on site, both during construction and occupancy
- Develop hazardous materials management plan for both construction and occupancy
- Develop a recyclable materials collection system for building users
- Minimize the amount of building to be built
- Consider renovation and reuse as alternatives to new construction
- Focus on adaptability of structures

Waste Management

The EPA Campus is designed to optimize waste management opportunities during design, construction and operation. Waste management occurs on many levels, beginning with efficient use of resources, a design approach that maximizes building longevity, and a thorough and systematic approach to reuse, recycling and responsible disposal of waste materials.

Efficient Building Design

Efficient building design conserves resources and reduces waste through design efficiencies. This issue is important when considering space planning efficiencies as well as volume, which standard net-to-gross calculations often overlook. For example, "interstitial" planning is a common strategy for providing services to laboratory areas. This approach requires extra ceiling height above the lab space through which services are routed. The overall effect is that the floor-to-floor height is boosted by as much as five to six feet in all lab areas, as well as in office areas that fall within the laboratory block in order to accommodate the necessary services. After reviewing the options, the EPA project team chose to make use of a service corridor to deliver utilities and accommodate future changes. As a result, the overall height of the building and total building volume was reduced, material consumption was lowered and access to the utilities was enhanced.

Waste Reduction

Modular design that is coordinated with standard building material dimensions can greatly reduce waste from trimming. Consequently, standard-size building materials were used wherever possible in the design and detailing of the EPA facility to minimize waste in manufacture and installation. Use of standard slopes for tapered roof insulation, for example, decreases waste by as much as 50 percent.

Increased Building Longevity

While it is common in the design and construction industry to design for a 30-year life cycle with cost paybacks limited to a three-five year time frame, EPA has a long-

term interest in this facility. In addition, the project team recognized that the actual use of a building often exceeds the projected design timeframes requiring extensive refurbishments and maintenance. To address these issues within the context of sustainability, the new facility was conceived as a "100-year" building and designed accordingly. Key elements like the facility's structure, the cladding, the flashing and the fireproofing are intended to survive with minimum repair for the projected life. The overall consequences of the extended design are a reduction in materials usage and the increased adaptability over the life cycle of the building.

Flexible Laboratory

Building Adaptability

Designing for adaptability is important because even if a building's physical structure is long-lived, overly specific building designs that cannot adapt to changing needs can become obsolete before their time. Ample ceiling height, a generous column bay and good access to daylight make the EPA facility an easily adaptable structure. Provisions have been made to accommodate growth of laboratory programs within the laboratory block itself. Approximately 20 percent of the space in the laboratory buildings is occupied by offices. This office space is convenient for lab workers but also serves as a built-in buffer for growth. If office space needs grow and lab needs shrink, more offices can be accommodated in the lab building. This "swing space" was important to creating a flexible facility design.

Collection and Handling of Recyclables

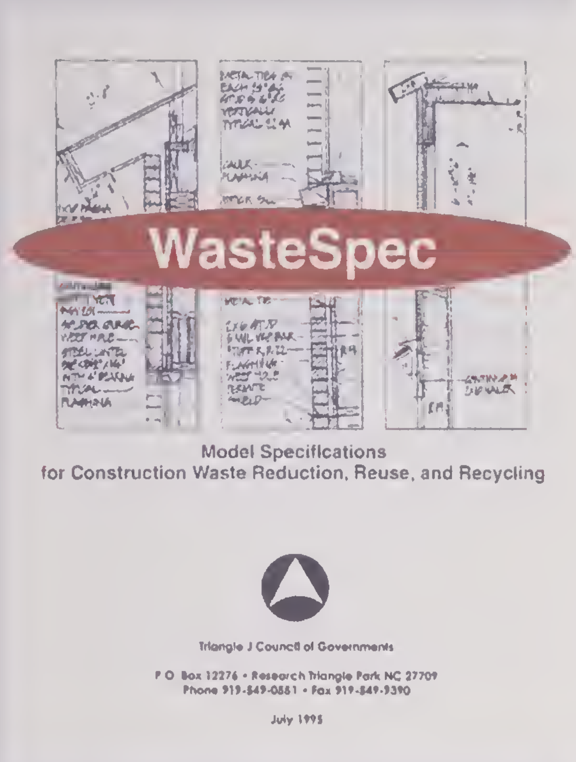
The EPA Campus has been designed to accommodate the recycling of paper, glass, aluminum, plastic and cardboard. Convenient collection locations have been provided near areas that generate large quantities of recyclable waste (such as copy rooms and galleys). These areas are located near elevators to aid collection. Consequently, collection areas were located in copy rooms and building break rooms where the majority of recyclables will be generated. In addition, the break rooms were located directly adjacent to the service elevator lobby, and the copy rooms were less than 50 feet away. The service elevator is used by janitorial staff to transport the recyclables to the loading dock via an underground service tunnel that moves material on electric carts. This means that recyclables can be transported to the staging area at the loading dock without having to pass through any public areas. The loading dock has been designed with ample room for staging of recyclables before pickup, and a compactor for cardboard has been provided.

Plan of typical floor circulation flow

Recycling and waste reduction is well integrated into the cafeteria design as well. Reusable china and flatware will be used in the cafeteria. Recycling collection areas will be built into the tray drop area in the cafeteria, and the vending areas. An organic waste recycler will be used for pre- and post-consumer compostables from food service.

Recycling Chutes

Recycling chutes are vertical shaftways that allow recyclables to be dropped to a collection area below. Chutes were initially evaluated for the EPA facility, with the service corridor acting as a lower-level zone to manage collection. Unfortunately, recycling chutes are most efficient in predominantly vertical buildings where relatively closely spaced chutes can accommodate occupants. However, in the five-story, approximately quarter-mile long floor plan of the EPA facility, recycling chutes were a costly and redundant vertical transport system that would have become a maintenance burden. Recycling chutes can also become maintenance problems if the wrong wastes are sent through. For example, sticky residue from soft drinks can attract pests or promote the growth of bacteria and mold. Instead, recycling containers were located near elevators, and the underground service tunnel was used to provide direct access to the loading dock.



Cover of WasteSpec, published 1995

Reuse of On-Site Materials

All material generated on the site from land-clearing activity and excavation is reused on site. Land-clearing debris remaining after the valuable materials have been sold as timber is shredded for use as mulch. The excess material is composted with topsoil as a soil amendment. Excavated topsoil is being stockpiled for reuse and excavated rock is crushed for use as structural fill.

Construction Waste Recycling

Construction waste occupies about 25 percent of the space at municipal landfills in the United States. To reduce the demand on landfills, construction and demolition waste landfills were created to offer a lower cost alternative to municipal landfilling for the construction industry. Debris that is essentially clean and inert can be dumped for a lesser fee than municipal waste because the landfill does not require a liner.

Three basic types of construction waste recycling are on-site separation, phase-based sorting by hauler and off-site sorting of mixed waste. Before developing a specification, research should include landfill and recycling tipping fees and the availability of recycling companies that will accept recyclable material. WasteSpec is a model waste specification that was created by the Triangle J Council of Governments in Research Triangle Park. The information applies to all parts of the country and a resource list in the appendix provides names and contact phone numbers for recycling coordinators for all 50 states, the Canadian provinces, Washington, D.C. and Puerto Rico.

CONSTRUCTION WASTE MATERIALS SPECIFIED FOR RECYCLING

1. **Land clearing debris:** Solid waste generated solely from land clearing operations, such as stumps and trees
2. **Concrete, masonry and other inert fill material:** Concrete, brick, rock, clean soil not intended for other on-site use, broken asphalt pavement containing no ABC stone, clay concrete, and other inert material
3. **Metals:** Metal scrap including iron, steel, copper, brass and aluminum.
4. **Untreated wood:** Unpainted, untreated dimensional lumber, plywood, oriented strand board, masonite, particleboard and wood shipping pallets
5. **Gypsum wallboard scrap:** Excess drywall construction materials including cuttings, other scrap and excess material
6. **Salvaged Materials:** Reusable lumber, fixtures and building supplies
7. **Cardboard:** Clean, corrugated cardboard such as used for packaging, etc.
8. **Paper:** Discarded office refuse such as unwanted files, correspondence, etc.
9. **Plastic buckets:** Containers for various liquid and semi-solid or viscous construction materials and compounds
10. **Beverage containers:** Aluminum, glass and plastic containers

The EPA project team chose to use on-site separation because clean separated recyclables have the highest value and many haulers will collect the separated material in the RTP area. The EPA Construction Waste specification lists materials recycled and requires the contractor to develop a construction waste management plan to be approved prior to the start of construction.

Gypsum Grinding

Gypsum can be problematic in landfills because it forms hydrogen sulfide gas under anaerobic conditions. The best way to solve the problem is through recycling and keeping the gypsum out of landfills. North Carolina's RTP area is one of the few regions in the country with an active gypsum recycling industry. The recycled material is not being reformed into gypsum at this time, but it is being made into chemical absorbents such as those used in cat litter. Gypsum also makes an excellent soil amendment if it is ground finely and used in the proper quantities.

The EPA Construction Waste specification gives the contractor the option of recycling gypsum or grinding it for use on the site. For on-site application as a soil amendment, 50 pounds per 1,000 square feet, or approximately one ton per acre, of material ground to a fine particle size can be incorporated into the soil surface. This quantity can be increased if a soil analysis is reviewed by and approval granted from the Solid Waste section of the North Carolina Department of Environment and Natural Resources.

Construction

Most construction processes impact the building site and beyond through excavation and related soil erosion, disruption of vegetation, wildlife habitat and topography, compaction of the soil from transportation onto the site, drainage into nearby water bodies, and even contamination of the site by hazardous materials when not properly controlled. Other environmental issues include construction waste, energy used during the construction processes and the effects of material installation on building indoor air quality.

The impact of these construction processes can be minimized through the creation and implementation of effective construction management plans, including rigorous employee education. Just as important, the general contractor should join the team as a partner with a stake in meeting the environmental goals of the project.

Groundbreaking ceremony, October 1997

Plant rescue

Plant rescue

Partnering for Construction

Prior to construction, EPA and the General Services Administration (GSA) held a partnering session with the general contractor and A/E representatives involved in construction administration. Typical partnering focuses on safety, quality, schedule and budget. For the EPA project, the environment was placed on equal footing. The environmental goals for the project were discussed and a training video on environmentally friendly construction practices was shown. This training video, produced in both English and Spanish, became required viewing for every construction worker on site.

The video describes the broad range of environmental initiatives included in the project, including environmentally preferable material specifications, tree protection, top soil preservation, construction practices to limit potential for contamination of future indoor air quality, and waste separation and recycling. Site workers and managers learned not just what is expected of them but why it is important, in the hope of enlisting each of them as willing partners in the creation of an environmentally friendly construction site. During clearing, grading and concrete production, no material left the site as waste, signaling successful reduction and reuse of materials.

Plant Rescue

While every effort was made to minimize the amount of land that had to be cleared for the project, EPA utilized plant rescues to help limit the impact of clearing by physically relocating plant material away from the construction limits before it was destroyed. A plant rescue involves volunteers entering an area slated for clearing, in this case the project site, to remove plants that otherwise will be bulldozed during the construction.

A delay in project start-up from winter 1996 to early summer 1997 afforded the perfect window of opportunity for a plant rescue operation, as spring is the ideal time to transplant native plants to maximize their chances for survival. Together with their neighbors, the National Institutes for Environmental Health Sciences (NIEHS), with help from the North Carolina Botanical Gardens at Chapel Hill, EPA saved more than 3,500 plants during several weekends in April and May 1997. Many plants were transplanted to the NIEHS Campus by volunteer employees to enrich the wooded understory in front of the NIEHS main building. The rest of the plants were donated to the Botanical Gardens and relocated by volunteers to public and private gardens in the area.

Reuse of Land-Clearing Debris

Land clearing generates enormous quantities of biodegradable and potentially useful organic material, none of which need be lost to landfills. During the clearing of the EPA site, the contractor successfully salvaged all cleared timber for either sawlogs or pulpwood, highlighting the usefulness of precious wood resources. The remaining woody debris was ground into mulch. Often the topsoil and mulch were mixed to facilitate composting of the mulch and amending the topsoil for future use on the site.

Limbs, stumps and other debris resulting from the site clearing operation was stacked up ready to be ground into mulch by portable tub grinders. With conventional construction, piles like these would be burned on the site, and the stumps would be hauled to a local landfill. On the EPA project, none of the clearing and grubbing wastes were disposed of off site, and no burning was allowed.

Land–clearing debris

Rock Crushing

In addition to the reuse of plant material from the construction site, reuse of excavated soil and rock from excavation debris reduces both material waste and transportation from hauling off-site. The contractor has used portable rock crushers on site to process rock from site excavations as well as scrap concrete, later in construction. There are two machines: the first is the actual crusher, which takes rocks up to 24" diameter and discharges material smaller than 3". The second machine is the sieve and screen, which takes the crusher product and separates the unwanted gradations and fractions to produce specific aggregates.

Although the excavated rock and weathered rock may not be durable enough to use as road aggregate, the contractor has used the product in his structural fills and backfill throughout the site. The aggregate material produced on site has been used for temporary haul roads and access during inclement weather. To date, the contractor has not hauled any rock waste from the project.

Debris grinding with tub grinder

Rock crusher

On-Site Concrete Batch Plant

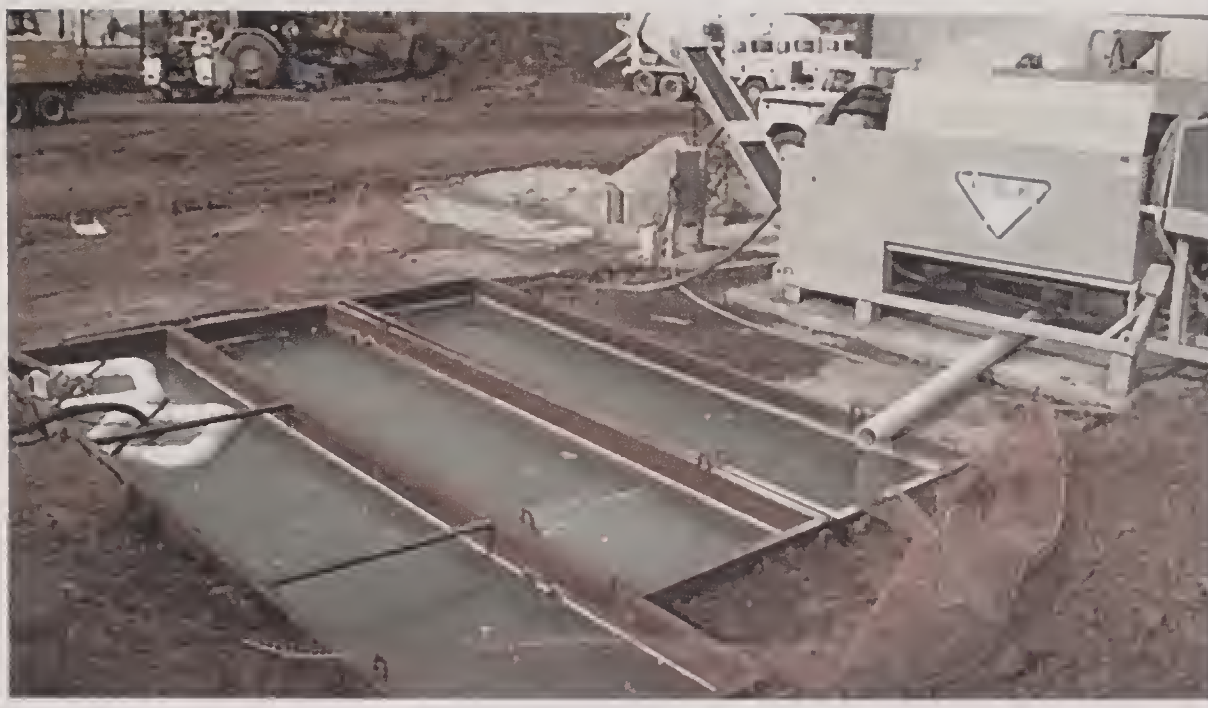
The construction contract offered the contractor the option to erect an on-site plant, provided it would require no additional clearing. An on-site plant was chosen due to economics and control over the supply. A portable concrete batch plant was erected on the site, in the south surface lot for the National Computer Center. One of the contractor's first activities was to rough grade this parking lot, the largest surface lot in the project, to prepare it for the batch plant.

Tremendous environmental benefits are realized by this decision, including the elimination of an estimated 75,000 highway miles of concrete transit truck traffic and a savings of 10,000 gallons of fuel.

On-site concrete batch plant

RotoReclaimer

The RotoReclaimer is a device installed at the concrete batch plant to eliminate concrete delivery truck washout wastes. The system is a prefabricated unit consisting of a rotating drum, conveyors and settling tanks. The entire process is self contained and generates no wastes. Like the batch plant itself, this device was not required by the contract but was something the contractor chose to employ. The environmental benefits of the decision, however, are apparent regardless of the motive.



The RotoReclaimer collects wastewater from the concrete mixer to wash and separate aggregate.

When an empty concrete transit mixer returns to the plant from the placement, its ramp is backed up to the stand pipe to be washed out. The RotoReclaimer pumps the reclaimed water into the truck mixer drum to clean it out. The waste slurry is then dumped into the center of the rotating drum of the RotoReclaimer, where it is washed and the fine and coarse aggregates are separated. The cleaned aggregates exit the device on two conveyors and are collected in stockpiles for reuse in the batching operation. The wash water is pumped into a series of three holding tanks where it settles to allow the cement to settle out. Clean water is recovered from the final tank and returned to the system to wash the next truck. Periodically, the settling tanks are allowed to dry and the solids are cleaned out to be processed through the rock crusher with the site rock and then reused.

Salvage of Demolition Materials for Reuse

New construction rarely addresses the reuse of salvaged materials, an important waste-reduction strategy. At the central utility plant, the existing precast concrete panels on the south walls had to be removed to make room for the plant expansion. The contractor removed the panels intact, loaded them directly to a

Dismantling precast concrete panels for reuse in plant expansion

waiting flatbed truck and stored them on the site to reinstall, where possible, on the expanded plant. This action saves materials, fabrication, delivery, and disposal costs compared with traditional demolition and replacement.

Construction Waste Recycling

Using aggressive programs to separate wastes at their sources, the contractors recovered 80% of the waste generated on site. Including site preparation wastes, this amounted to about 20 million pounds of resource material that would normally have been sent as “waste” to landfills. Separate waste hoppers were provided for drywall, metal, cardboard, wood and other wastes in the buildings and special crews hauled the hoppers to specially-marked dumpsters. Routine visual checks ensured that recycling haulers would leave the site with uncontaminated loads

Use of Recycled Content Building Materials

While minimum recycled content requirements were specified for many construction materials, good partnering for construction has led to materials with even better recycled content than originally specified. Recognizing the environmental goals of the project, the general contractor has searched for and found some materials with higher recycled content than the minimums required in the specification. For example, all rebar is made from a mill that uses the electric arc process, a process that utilizes 100 percent recycled scrap steel.

Another instance in which the general contractor volunteered additional use of recycled content was for the roadway base course. The use of a minimum of 20 percent recycled concrete aggregate was originally specified for the roadway base course, however the requirement was one of a few environmental specifications deleted when the project went out for rebid. Zero aggregate base course was used due to the unavailability of local waste materials of acceptable quality and gradation. Now that the project is under construction, however, the general contractor has volunteered to use 100 percent crushed concrete scrap for the base course when salvaged material is available.

Submittals Review During Construction

Review of submittals is a particularly important step in the construction process. Submittal packets were compiled by the various subcontractors and sent to the project team by the general contractor, often including substitutions to the products specified. Environmental and other specifications must be tracked by the architects to avoid getting lost in the process and defeating the team’s efforts in the final stages of the project.

In the EPA Campus, for example, the main building’s specifications clearly listed volatile organic compound (VOC) limits for paint products as well as prohibited hazardous substances, for which certification of compliance was required. Yet in the various paint submittal packets received, many of the substitutions included clearly non-compliant products. Midway it was discovered that the paint subcontractor did not have a copy of the environmental criteria. Individual substitutions were rejected based upon noncompliance with these criteria until full compliance, with little exception, was achieved–a process that took over six months. This illustrates the importance of maintaining a consistent level of attention to the integrity of the specifications, particularly for environmental criteria which are less familiar to many of the parties involved.

Constant Vigilance

Through close attention to detail at every step of the process, the project team has seen most of the environmental design goals of the new EPA campus come to fruition. And for every small detail that has not ultimately materialized, there have been new, unexpected environmental gains such as the voluntary concrete recycling program offered by the contractor. The key to this success has been the commitment by all parties to the common goals of high quality, cost-effectiveness, and environmental stewardship.

As the chapters of design and construction draw to a close, and operations begin, EPA continues its commitment to make this a model, sustainable campus–still climbing the greening curve.

ENDNOTES

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4 *Report to Congress on Indoor Air Quality, Volume II: Assessment and Control of Indoor Air Pollution*, U.S. Environmental Protection Agency (EPA), Office of Air and Radiation (OAR), (Washington, DC, 1989).

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6 Lumen Micro, Lighting Technologies Inc., software that provides tools to create, simulate and analyze lighting layouts for both indoor and outdoor applications.

7 *Sparks, L.E.; Exposure Version 2: A Computer Model for Analyzing the Effects of Indoor Air Pollutant Sources on Individual Exposure,* EPA-600/8-91-013 (NTIS PB91-507764). Air Pollution Prevention and Control Division, Research Triangle Park, NC, April 1991.
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